June, 1942
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Metal Progress

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By Joseph H. Jones
Central Alloy District
Republic Steel Corp.
Massillon, Ohio

National Emergency Steels

NE 8600 to 8900

MEMBERS of the War Production Board and its predecessors realized that the 2500 alloy steel analyses produced in this country constituted an obstacle to maximum production. The real necessity for many of the high alloy steel applications was also questioned, as well as the possibility of continued procurement of necessary alloying metals for them.

To deal with these and various related problems, a committee of metallurgists was formed which worked under the Technical Advisory Committee to the War Production Board. Its organization was described in METAL PROGRESS for March, and its chief duty was to reduce the alloy steel analyses to the absolute minimum in number, and to conserve alloying elements by combining relatively small quantities in such a manner as to give the greatest results per unit used, thus to conserve the alloying metals returning in scrap from the ordnance plants. With these objectives in mind and in collaboration with the best metallurgical talent in this country, the NE Steel Specifications were written.

While the science of applied metallurgy has progressed to the point that physical properties and other characteristics of a given analysis can be quite accurately predicted, actual experience in the shop and fabricating plant is still the final proof. However, the NE analyses as written furnished an important starting point and such a starting point obviously had to precede the melting of steel and its fabrication into finished parts. Approximately 9000 tons of the NE chromium-nickel-molybdenum steels described in this article have already been melted and sufficient quantities have been processed into finished parts to supply some information as to how it compares with the original S.A.E. grades. Small lots can now be ordered from the eight steel warehouses now stocking them.

Over-all, the field reports on NE chromium-nickel-molybdenum steels are favorable and indicate that these grades are doing an excellent job. Seldom does a new analysis start off with so much praise and so little criticism as this group has.

Various steel producers accepted the job of making complete laboratory tests on commercial heats, Republic Steel Corp.'s Central Alloy District being assigned NE 8600 to 8900. Steels NE 8724 and 8744 were not tested in this first investigation because they are very close to NE 8620 and 8739 which were studied. Even though the results are from individual heats, we have every reason to believe they are representative and can be relied upon if interpreted with ordinary caution. A summary of our tests follows.

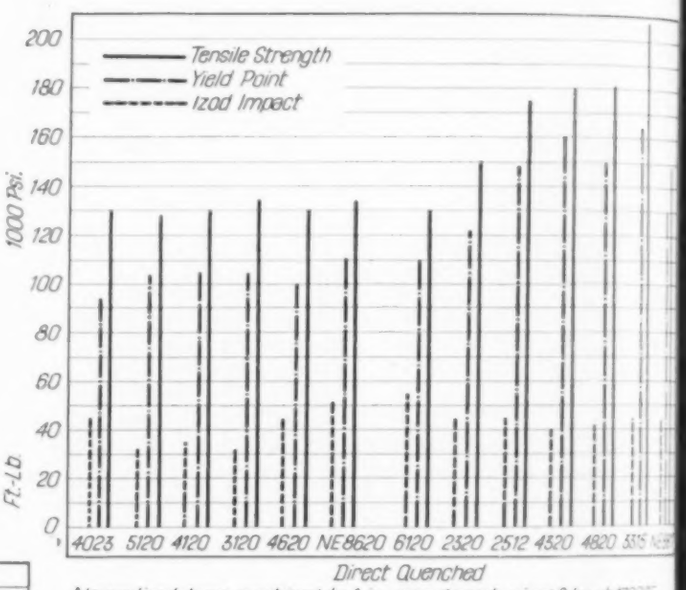
Electric furnace heats (most of them from 35-ton furnaces) were made by routine commercial methods. Specifications aimed at and analyses made are shown in Table I. Square bars were forged to 1¼, 2¼, 3¼, 4¼ and 5¼-in. squares; rounds and test pieces were machined from the appropriate square bars. Openhearth steels will be indistinguishable from the electric furnace steels tested; the latter show their superiority in surface condition and cleanliness — matters that do not affect the mechanical tests made and here reported.

Table I — Chemical Specifications and Actual Analyses of Test Heats

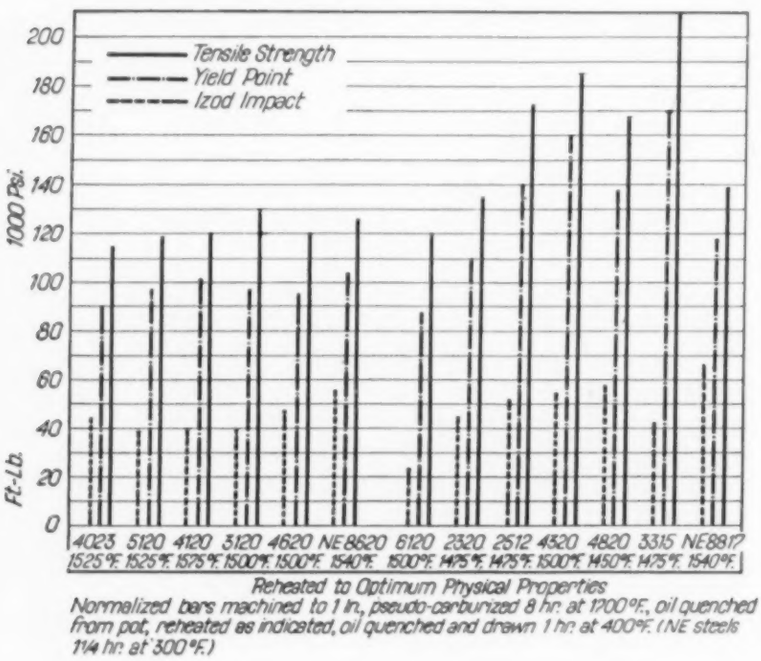
Steel		C	Mn	P	S	Si	Ni	Cr	Mo
NE 8620	Spec.	0.18-0.23	0.70-0.95	0.040 max.	0.040 max.	0.20-0.35	0.40-0.60	0.40-0.60	0.15-0.25
	Ladle	0.195	0.80	0.014	0.014	0.23	0.43	0.52	0.22
	Check	0.19	0.80	0.015	0.015	0.23	0.46	0.52	0.22
NE 8630	Spec.	0.27-0.33	0.70-0.95	0.040 max.	0.040 max.	0.20-0.35	0.40-0.60	0.40-0.60	0.15-0.25
	Ladle	0.28	0.78	0.015	0.016	0.24	0.40	0.49	0.22
	Check	0.304	0.80	0.014	0.015	0.25	0.42	0.49	0.22
NE 8739	Spec.	0.35-0.42	0.75-1.00	0.040 max.	0.040 max.	0.20-0.35	0.40-0.60	0.40-0.60	0.20-0.30
	Ladle	0.39	0.83	0.015	0.016	0.30	0.47	0.48	0.25
	Check	0.41	0.86	0.015	0.019	0.31	0.46	0.47	0.26
NE 8749	Spec.	0.45-0.52	0.75-1.00	0.040 max.	0.040 max.	0.20-0.35	0.40-0.60	0.40-0.60	0.20-0.30
	Ladle	0.53	0.80	0.015	0.015	0.24	0.45	0.53	0.25
	Check	0.546	0.83	0.015	0.015	0.23	0.46	0.52	0.27
NE 8817	Spec.	0.15-0.20	0.70-0.95	0.040 max.	0.040 max.	0.20-0.35	0.40-0.60	0.40-0.60	0.30-0.40
	Ladle	0.195	0.84	0.015	0.015	0.29	0.48	0.52	0.33
	Check	0.192	0.86	0.013	0.013	0.29	0.48	0.49	0.35
NE 8949	Spec.	0.45-0.52	1.00-1.30	0.040 max.	0.040 max.	0.20-0.35	0.40-0.60	0.40-0.60	0.30-0.40
	Ladle	0.48	1.11	0.018	0.017	0.29	0.47	0.52	0.36
	Check	0.49	1.10	0.018	0.015	0.27	0.52	0.51	0.38

Properties of Carburized Core

Samples of NE Steels 8620 and 8817 were heat treated and tested so as to get figures to compare with those published by American Iron & Steel Institute for the conventional carburizing steels in "Contributions to the Metallurgy of Steel; No. 5; Possible Alternates for Nickel, Chromium, and Chromium-Nickel Constructional Alloy Steels". In our tests 5-in. lengths were cut from the 1¼-in. square bars and normalized by heating 1½ hr. at 1650° F. and air cooling. These bars were then machined to 1 in. diameter, pseudo carburized by packing in mica and heating at 1700° F. for 8 hr. Some samples were oil quenched direct from the pot, machined into standard test bars and tested. Other samples were air cooled, then reheated to 1525 or to 1550° F., as was appropriate, for 75 min., oil quenched and drawn 75 min. at 300° F.; test bars were then machined and tested. A summary of these tests is shown in Fig. 1 and 2, above; the diagrams also contain graphical data for comparable S.A.E. steels, treated almost identically.



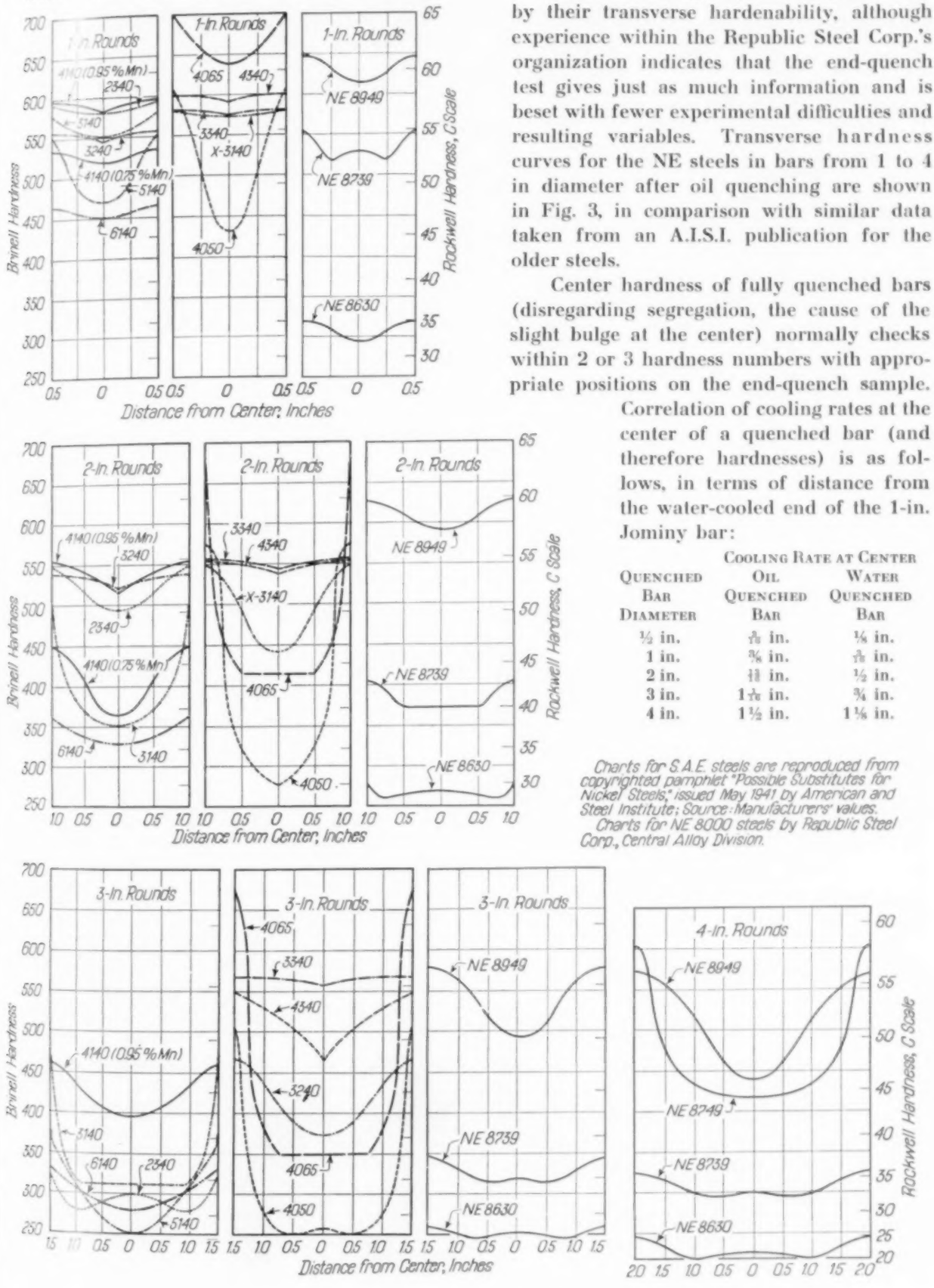
Normalized bars machined to 1 in., pseudo-carburized 8 hr. at 1700°F., quenched from pot and drawn 1 hr. at 400°F. (NE steels drawn 1¼ hr. at 300°F.)



Normalized bars machined to 1 in., pseudo-carburized 8 hr. at 1700°F., oil quenched from pot, reheated as indicated, oil quenched and drawn 1 hr. at 400°F. (NE steels 1¼ hr. at 300°F.)

Figs. 1 and 2 — Tensile Strength, Yield Strength and Izod Notch Bar Value for Carburized Cores of NE8620 and NE8817 in Comparison With Those of Conventional Alloy Steels (Republic Steel Corp., Central Alloy District, American Iron & Steel Institute)

Fig. 3 — Hardness Traverses Across Oil Quenched Bars of NE 8600 to 8900 Steels, in Comparison With Similar Curves of Conventional S.A.E. Steels



Transverse Hardenability

Some metallurgists prefer to grade steels by their transverse hardenability, although experience within the Republic Steel Corp.'s organization indicates that the end-quench test gives just as much information and is beset with fewer experimental difficulties and resulting variables. Transverse hardness curves for the NE steels in bars from 1 to 4 in diameter after oil quenching are shown in Fig. 3, in comparison with similar data taken from an A.I.S.I. publication for the older steels.

Center hardness of fully quenched bars (disregarding segregation, the cause of the slight bulge at the center) normally checks within 2 or 3 hardness numbers with appropriate positions on the end-quench sample. Correlation of cooling rates at the center of a quenched bar (and therefore hardnesses) is as follows, in terms of distance from the water-cooled end of the 1-in. Jominy bar:

Quenched Bar Diameter	Cooling Rate at Center: Oil Quenched Bar	Water Quenched Bar
½ in.	⅛ in.	1/16 in.
1 in.	⅜ in.	⅛ in.
2 in.	11/16 in.	½ in.
3 in.	1 7/16 in.	¾ in.
4 in.	1½ in.	1⅛ in.

Charts for S.A.E. steels are reproduced from copyrighted pamphlet "Possible Substitutes for Nickel Steels," issued May 1941 by American and Steel Institute; Source: Manufacturers' values. Charts for NE 8000 steels by Republic Steel Corp., Central Alloy Division.

Table II — Physical Properties of NE 8630, Heat Treated in Various Sizes. Quenching Temperature: 1550° F.

Draw	Tensile Properties				Izod	Brinell of Izod Test Bars	Fracture
	Yield	Ultimate	Elong.	R.A.			
			Treated in 0.530-In. Rounds				
400° F.	225,000	245,500	11.0	37.3	14	477	100% crystalline
500	208,000	229,000	10.0	38.8	16-17	444	100% crystalline
600	190,000	210,000	11.5	44.9	18-19	415	100% crystalline
700	181,000	200,500	11.5	46.3	25	388	70% crystalline
800	161,000	181,500	12.0	50.6	31-32	363	70% crystalline
900	146,000	165,000	15.5	57.3	45-47	340	90% silky
1000	139,000	152,000	17.0	61.0	51-52	321	90% silky
1100	119,000	134,000	18.5	63.6	62-64	255	20% woody
1200	100,000	115,000	22.5	68.2	86-90	228	40% woody
			Treated in 1-In. Rounds				
400° F.	152,000	172,500	12.0	41.9	21-23	363	100% crystalline
500	142,000	162,000	13.0	43.9	24-25	341	90% crystalline
600	140,000	159,000	14.0	53.3	31-32	331	50% crystalline
700	136,500	156,000	14.0	54.7	32-33	331	50% crystalline
800	125,500	145,500	15.5	57.3	51-52	302	10% woody
900	122,000	140,500	17.0	59.8	52-54	302	10% woody
1000	114,000	132,000	18.5	61.0	68-69	269	40% woody
1100	104,000	121,500	20.6	63.6	74-75	255	40% woody
1200	87,500	105,000	24.0	68.2	96-101	207	40% woody
			Treated in 2-In. Rounds				
900° F.	100,000	121,000	19.0	63.6	74-78	241	20% woody
1000	94,500	114,000	21.0	65.9	83	228	20% woody
1100	87,500	108,000	22.0	65.4	88-90	217	40% woody
			Treated in 3-In. Rounds				
900° F.	92,500	113,500	21.0	63.6	82-83	228	40% woody
1000	92,000	112,500	22.0	65.9	86-88	217	40% woody
1100	81,500	103,000	24.0	67.0	93-95	197	40% woody
			Treated in 4-In. Rounds				
900° F.	92,000	114,000	19.0	56.0	81-84	228	40% woody
1000	88,000	109,500	20.0	56.0	84-86	217	40% woody
1100	79,000	102,000	23.0	62.4	95-97	197	40% woody
			Treated in 5-In. Rounds				
900° F.	87,000	108,500	19.5	56.0	82-84	217	40% woody
1000	84,500	106,000	21.0	57.3	85-88	207	40% woody
1100	77,000	99,500	22.0	58.5	99	179	40% woody

Large bars of steel NE8949 are considerably softer in the center regions than would be predicted by the hardenability curve in Fig. 4 and the above relation but it is very difficult to section a fully hardened 4 or 5-in. bar and smooth it for testing without slight heating at the grinder (and consequent tempering).

McQuaid-Ehn Grain Size

Representative samples from each heat were carburized at 1700° F. for 8 hr. and the pot was slowly cooled in mica. Samples were then sectioned, polished, and etched for examination of the hypereutectoid case. Results follow.

Steel	Carbon	Grain Size
NE 8620	0.19	7 to 8 (some 6)
NE 8630	0.30	7 to 8
NE 8739	0.41	7 to 8 (some 6)
NE 8749	0.55	7 to 8 (some 6)
NE 8817	0.19	7 to 8
NE 8949	0.49	7 to 6

End-Quenched Hardenability

Standard General Motors Corp. hardenability tests (Jominy end-quench test) were made on 1-in. round specimens, 4 in. long, machined from each heat. Bars were held at temperature, (1525 to 1550° F.) for 45 min., then placed vertically in the fixture, and cooled by a jet of cold water striking the scale-free lower end only. Small flats were then ground down the side. Rockwell tests on "C" scale made at $\frac{1}{16}$-in. spacings and results are plotted in Fig. 4. From these curves it can be seen that the chromium-nickel-molybdenum steels of the NE 8000 series have a wide range of hardenability and by correct choice and treatment can be adapted to a great variety of services.

NE 8949 has unrivalled depth hardening properties, truly amazing for the moderate total of alloying elements present. The car-

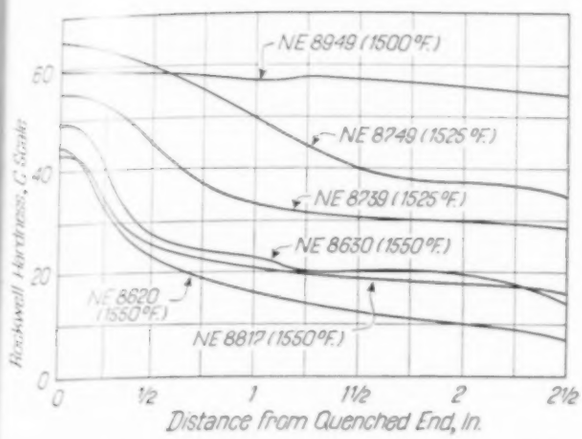


Fig. 4 — End-Quench Tests Showing Hardenability of the Cr-Ni-Mo Steels of the NE 8000 Series, (Republic Steel Corp., Central Alloy District)

burizing grades NE 8620 and 8817 have characteristics much like the old steels whose hardenability curves were shown in the article on the National Emergency steels in METAL PROGRESS in March, page 342, when allowance is made for the fact that the latter curves are all for steels with 0.30% carbon.

Influence of Mass and Heat Treatment

A very large number of tests were made so that complete information would be available as to the properties of the four non-carburizing NE heats, normalized from 1650° F., oil quenched from optimum temperature and drawn at various heats. Much of this work was duplicated on bars of sizes ranging from 0.530 in. to 5 in. diameter (all tests taken from center position), thus giving the "mass effect" and a further check on hardenability. Time at quenching heat and at drawing heat was roughly 1 hr. per in. of diameter. Numerical values are shown in the adjoining Tables II, III, IV and V.

Hardness of the tensile test bars did not

Table III — Physical Properties of NE 8739, Heat Treated in Various Sizes. Quenching Temperature: 1525° F.

Draw	Tensile Properties				Izod	Brinell of Izod Test Bars	Fracture
	Yield	Ultimate	Elong.	R.A.			
			Treated in 0.530-In. Rounds				
400° F.	260,000	282,500	8.5	29.2	7	555	100% silky
500	245,500	261,000	10.0	34.1	8-10	514	100% silky
600	222,000	245,000	12.0	43.4	11	495	80% silky
700	203,000	224,500	12.0	44.9	11-12	444	80% silky
800	181,000	202,000	13.5	49.2	23-24	415	50% silky
900	166,000	186,000	14.0	51.0	33-34	363	50% silky
1000	151,000	168,500	15.5	54.7	38-39	340	15% woody
1100	140,000	155,500	17.5	56.0	54-55	302	20% woody
1200	112,500	127,500	21.0	62.4	69-70	241	40% woody
			Treated in 1-In. Rounds				
400° F.	242,000	263,000	8.0	25.8	8-9	555	100% silky
500	236,000	257,500	8.5	35.7	9-11	477	100% silky
600	208,500	230,000	9.0	37.3	11-12	461	80% silky
700	198,500	220,000	9.0	38.8	12-14	444	80% silky
800	179,000	200,500	10.5	46.3	20-21	415	70% silky
900	162,000	181,000	13.0	50.6	27-28	388	70% silky
1000	152,500	170,000	14.0	53.3	40-43	341	20% woody
1100	132,000	148,500	16.0	57.3	49-50	302	20% woody
1200	110,500	125,500	20.5	61.0	70-73	269	40% woody
			Treated in 2-In. Rounds				
900° F.	129,000	150,000	16.0	56.0	48-49	321	20% woody
1000	123,500	144,000	17.0	56.0	52-55	311	20% woody
1100	106,000	127,500	18.5	61.0	69-72	269	20% woody
			Treated in 3-In. Rounds				
900° F.	120,500	141,000	15.5	56.0	45-50	302	20% woody
1000	116,500	136,000	18.0	59.8	60-61	286	20% woody
1100	110,000	122,000	20.0	62.4	69-72	241	20% woody
			Treated in 4-In. Rounds				
900° F.	118,500	140,000	16.0	51.9	45-48	286	20% woody
1000	115,500	135,500	17.0	53.3	54-58	269	20% woody
1100	101,500	123,500	19.0	57.3	74-75	241	20% woody
			Treated in 5-In. Rounds				
900° F.	112,500	132,000	16.0	51.9	40-44	286	20% woody
1000	103,500	125,000	17.0	54.7	52-56	262	30% woody
1100	96,500	118,000	20.0	58.5	66-70	241	30% woody

always correspond with the hardness of the Izod bars, quoted in the tables, and this should be borne in mind when appraising the figures for ultimate.

Thermal Critical Points

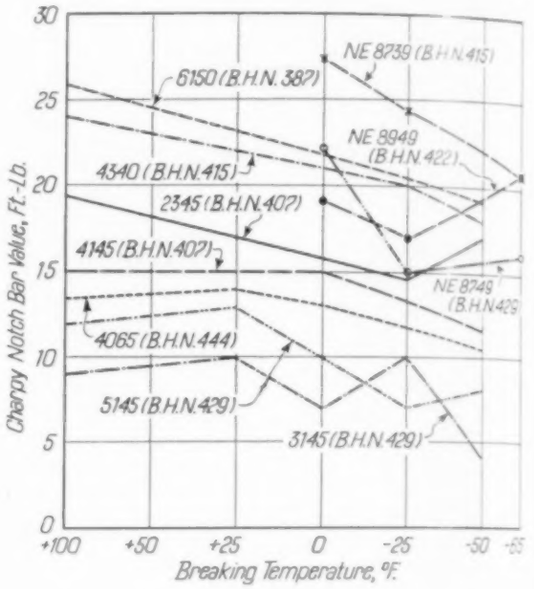
Bars 3 in. long by 0.75 in. diameter were prepared for the Rockwell dilatometer and curves automatically drawn to determine the thermal critical points. Heating and cooling were at the rate of 240° F. per hr., and the following arrests were noted:

Steel	Ac_1	Ac_3	Ar_3	Ar_1
NE 8620	1340° F.	1530° F.	1415° F.	1270° F.
NE 8630	1350	1470	1360	1220
NE 8739	1350	1450	1300	1180
NE 8749	1340	1420	1240	1210
NE 8817	....	1520	1420	1300
NE 8949	1300	1350	845	750

Toughness at Low Temperatures

Sub-zero Charpy impact tests were made on three of the steels that would likely be used for low temperature equipment. For this work 1¼-in. square bars were normalized (air cooled from 1650° F.). Test pieces 0.394-in. square were then machined from the center position, and notched with standard V-notch for Charpy test. Half of the bars were then oil quenched and drawn to as near Brinell hardness 400 as possible, extreme care being taken to prevent any change in the surface chemistry. Bars were then immersed in a mixture of alcohol and dry ice, held 30 min. at zero, −25° F. and −65° F. respectively, and quickly tested in the impact machine. Results for the hardened bars are shown in Fig. 5, and are evidently comparable with the best of the old S.A.E. alloy steels.

Fig. 5 — Charpy Notch Bar Values at Sub-Normal Temperatures for NE8739, 8749 and 8949. (Republic Steel Corp., Central Alloy District). Comparisons are shown with S.A.E. steels — all heat treated to 400± hardness — manufacturer's values taken from American Iron & Steel Institute's bulletins



The normalized bars had noticeably

Table IV — Physical Properties of NE 8749, Heat Treated in Various Sizes. Quenching Temperature: 1500° F.

Draw	Tensile Properties				Izod	Brinell of Izod Test Bars	Fracture
	Yield	Ultimate	Elong.	R.A.			
			Treated in 0.530-In. Rounds				
800° F.	....	190,000	Broke in shoulder		8-10	495	100% silky
900	178,000	200,500	10.5	41.9	14	444	100% silky
1000	168,500	190,000	12.5	43.4	17-19	415	70% silky
1100	145,000	165,000	15.0	49.2	28-31	375	70% silky
1200	126,500	145,500	18.0	54.7	46-49	321	60% silky
			Treated in 1-In. Rounds				
800° F.	206,500	228,000	10.0	37.3	10-12	444	100% silky
900	183,500	205,000	12.0	41.9	16-17	415	80% silky
1000	166,000	187,000	13.5	43.4	22-24	388	80% silky
1100	146,500	167,500	16.0	49.2	34-36	341	50% silky
1200	127,500	145,000	17.0	53.3	54	321	50% silky
			Treated in 3-In. Rounds				
900° F.	169,500	191,000	11.0	40.4	18	388	80% crystalline
1000	154,000	174,500	13.3	47.8	29-30	363	80% crystalline
1100	129,500	149,500	16.5	56.0	46-48	302	80% crystalline
			Treated in 4-In. Rounds				
900° F.	155,000	176,500	13.5	46.3	20-21	363	85% silky
1000	141,000	162,000	15.0	50.6	29-33	321	85% silky
1100	130,000	150,500	16.0	53.3	44-46	311	80% silky

lower notch bar strength than the quenched and drawn test pieces. Normalized NE 8739 with Brinell hardness of 262 had Charpy values close to three-quarters those shown in the figure; normalized NE 8949 with Brinell hardness 363 had values of only 4 to 6 ft.-lb. at the low temperatures, zero and below.

Coarsening Temperatures

Normalized samples ⅜ by 1¼ in. square were oil quenched from a series of rising temperatures and fractured to determine the nature of the fracture. Fracture grain size was estimated by comparing with Shepherd standards, which correspond fairly closely with the same number as rated by American Society for Testing Materials' standards for austenitic grain size measured with a microscope.

Steel NE 8620 had crystalline fracture No. 5 when quenched from 1400 and 1450° F.; a slightly woody to medium woody fracture No. 7 at 1500 and 1550° F., and fracture grain size No. 7 from 1600 to 1750° F., woody with trace of fine crystalline.

Steel NE 8630, when quenched from 1400 and 1450° F. had crystalline edges of No. 5 grain size and silky center of No. 7 grain size. Oil quenched within the range 1500 to 1650, Shepherd fracture was No. 7, silky and slightly woody, and at 1700 to 1750 the fracture was silky and grain size slightly finer.

Steel NE 8739 had crystalline fracture, size 4 to 5 at 1400° F., and size 7 to 8 at higher temperatures. Fracture was rated "silky" when quenched from 1450, 1500 and 1550; a slight woody appearance entered the pieces quenched from higher temperatures.

Steel NE 8817 had Shepherd rating No. 5 to 6 when oil quenched from 1400 and 1450° F.; the appearance was 80% silky and 20% woody; at 1500° F. the grain size was the same but the fracture was 90% woody. Quenched from 1550, 1600 and 1650° F. the fracture was woody and grain size No. 7, coarsening slightly to No. 6 to 7 at 1700 and 1750° F.

Steel NE 8949 had crystalline fracture, grain size No. 5 at 1400° F., and No. 5 to 6 at 1450° F. The grain size after oil quenching from 1500° and higher rated No. 7 by Shepherd standard; at 1500° F. the fracture was rated crystalline and slightly woody; at 1550 and 1600° F. medium woody and crystalline; at 1650 to 1750° F. woody and fine crystalline.

Table V — Physical Properties of NE 8949, Heat Treated in Various Sizes. Quenching Temperature: 1500° F.

Draw	Tensile Properties				Izod	Brinell of Izod Test Bars	Fracture
	Yield	Ultimate	Elong.	R.A.			
			Treated in 0.530-In. Rounds				
800° F.	209,000	230,000	12.0	44.9	15-18	415	100% silky
900	185,000	205,000	13.0	46.3	20-25	388	100% silky
1000	168,000	188,500	15.0	50.6	34-35	375	80% silky
1100	148,500	166,500	17.0	53.3	45-48	321	50% woody
1200	125,000	141,500	20.0	59.8	75-80	269	70% woody
			Treated in 1-In. Rounds				
800° F.	211,000	233,000	10.0	41.9	10-12	461	80% silky
900	190,000	211,000	10.0	44.9	14-15	415	80% silky
1000	172,500	192,000	13.5	47.8	22-25	401	80% silky
1100	154,000	173,500	15.5	51.9	39-45	352	50% woody
1200	133,500	151,000	18.0	57.3	54-55	302	50% woody
			Treated in 2-In. Rounds				
900° F.	187,000	207,000	12.0	44.9	15-16	415	100% silky
1000	172,500	190,000	12.5	47.8	24	388	100% silky
1100	150,000	167,000	15.0	51.9	43-46	352	80% silky
			Treated in 3-In. Rounds				
900° F.	183,500	203,000	10.0	38.8	16-17	401	100% silky
1000	167,500	185,000	12.5	46.3	30-31	375	90% silky
1100	145,500	161,500	15.0	53.3	48-49	331	70% silky
			Treated in 4-In. Rounds				
900° F.	180,000	198,500	9.0	37.3	12-14	401	100% silky
1000	162,500	181,000	13.5	43.4	26	375	90% silky
1100	145,000	161,000	15.0	53.3	48-49	321	70% silky
			Treated in 5-In. Rounds				
900° F.	170,500	189,500	8.5	29.2	15-16	388	90% silky
1000	162,500	180,000	11.5	37.3	27-28	363	90% silky
1100	142,500	158,500	15.0	48.6	46-47	321	70% silky

An Eminent Living Metallurgist

Frederick George Hughes

Our Biographical Dictionary

"THEY FOUND A WAY" is the title of a book describing Connecticut's pioneering contributions to the development of our country. A considerable portion deals with the early history of the northwestern part of the state, and especially its mining and iron smelting industry which played so important a part in the last century. In this tiny area, 20 miles square, almost every brook furnished power to blow a charcoal furnace smelting Salisbury ores. Thereabouts grew up a large number of pioneer iron and steel manufactories.

Among the men of the Cornwall section was the grandfather of FREDERICK G. HUGHES and into this environment he was born. The tradition of iron and steel was in his blood. It is but natural, then, that FRED was working with steel throughout his whole career — as indeed were his ancestors in the Cornwall Hills of Connecticut. Early in life he learned the meaning of sweat and toil in the small shop, a training which built into him the sturdy physique so invaluable in later years of strenuous industrial activity. It was his destiny to view the decline of the iron smelting industry in Connecticut, yet to take an important hand in the transition when steel, its heat treatment and use, advanced from the period of the artisan imbued with tradition to the era of the scientist trained in the profession of treatment and the engineer trained in the knowledge of its applications. Graduating from Yale University as a mechanical engineer in 1900, he entered the employ of the Bethlehem Steel Co. as a draftsman. In 1901 he entered the experimental ordnance department, remaining there until 1905, when he became chief engineer of the Driggs-Seabury Ordnance Corp. of Sharon, Pa. His contributions in this field of ordnance engineering have had a lasting effect on gun design.

Beginning in 1907, he was instrumental in converting Driggs-Seabury from an ordnance concern into one of the then largest automobile parts manufacturers, and was among the first to recognize the advantages of pressed steel frames and other parts which have become so important to the modern automobile. It was in this period that FRED HUGHES invented the present design of pressed steel rear axle which now has such universal acceptance, and was among the first to apply scientific analysis to the bearing loads in chassis complements.

In 1911 he came back to Connecticut, joining the New Departure Mfg. Co., then primarily known as a maker of coaster brakes for bicycles, but which had begun in 1906 to make "anti-friction" bearings. This new industry was at the dawn of the era of speed and it is in this field that FREDERICK GEORGE HUGHES' greatest contributions to engineering, manufacture and industry have been made. This new era made it necessary to find a way to "keep them rolling" and the growth of the New Departure Mfg. Co. from those humble beginnings to its present tremendous volume of production is a marked tribute to his versatility and imagination, accompanied always by a great capacity for work. Serving in the capacity of chief engineer, production manager, and then as vice-president and assistant general manager during the years 1911 to 1933, he fostered the development of many vital phases of the ball bearing industry.

His enthusiasm for things scientific and exact stimulated the development of laboratory and research facilities in advance of the times. His interest in and insistence on quality of material and product was a very considerable factor in the development of metallurgical quality in ball bearing steel; in this way he became responsible for its initial production in America and thus stimulated our development of electric furnace alloy steel.

His desire to find a way pioneered the spheroidization heat treatment of ball wire, necessitating a new practice in annealing and a new type of furnace. This also initiated the practice of cold heading of balls from domestic wire (high carbon, high chromium steel). His constant search for newer and better ways of making and doing better things is a continuing stimulus to his associates. The spirit of "try it" and "take a chance" has resulted in the advance, through research and development, of knowledge and methods which have made New Departure probably the world's largest producer of anti-friction bearings, through never losing sight of the first requirement — quality.

HUGHES became general manager of New Departure Division of General Motors Corp. in 1933, a position he holds today. In spite of the added executive duties he retains the same enthusiastic stimulating attributes which have always been his. He was director and president of the ⊕ in its early policy-forming days. Active in many civic and business enterprises in his community and state, he received a National Pioneers Award in recognition of his many-sided interests and his capacity for work.

His is the heritage of toil and sweat, the spirit of the pioneer who finds a way. ⊕

Modern Methods and Equipment for Malleable Iron

Reported by
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TEN PAPERS concerning the various phases of malleable iron production were presented as a part of the annual program for the American Foundrymen's Association in Cleveland late in April. In view of the fervent state of activity in industry, it was surprising that the papers were read by the respective authors with only one exception. Interest in the subject was further attested by the fact that almost every chair was occupied for both sessions, with little or no straggling; the number of men participating in the discussions was also quite large.

A forecast of the symposium as a whole, understandable even by one not actively engaged in the production of malleable iron, was given by HARRY A. SCHWARTZ, manager of research for National Malleable and Steel Castings Co. This was an admirable setting for the entire series of papers, as each of the authors subsequently discussed topics related to some one of the factors outlined by Dr. SCHWARTZ in his paper on "Principles of Graphitization".

It may be recalled that the chemical composition of white irons is adjusted so as to suppress primary graphitization during freezing, but elements promoting carbide decomposition — silicon for example — are kept as high as possible for the purpose of decreasing the time required for subsequent malleabilization. Liquid cast iron always *tends* to solidify with the separation of graphite, but the mold may take heat away faster than it is liberated by freezing so that solidification occurs at temperatures below the normal freezing point. Such supercooling was said to suppress graphite formation during freezing, so that white iron castings are produced.

Dr. SCHWARTZ explained the malleableizing process as consisting of the solution of iron carbide in iron (austenite), its decomposition, and the migration of the carbon atoms to points where they can readily precipitate as graphite nodules. Factors influencing the *time* required for this series of actions include holding temperature, composition of the iron, and items determining the number of nuclei (which eventually become temper carbon nodules).

The effect of temperature upon the rate of graphitization was attributed to the metastable condition of iron carbide. The relative immobility of the atoms at low temperature is replaced by an opportunity for chemical reaction as the temperature is raised. Within certain limits at least, the higher the holding temperature, the faster will be the rate of decomposition of iron carbide into its constituent elements.

Some facts about the effects of certain elements upon graphitization are known but there is much to be learned as to how they produce a characteristic effect. Stating that chromium, for example, retards graphitization because it stabilizes the carbide is only another way of saying it retards graphitization; such a statement therefore adds nothing to the picture. Sulphur and some related elements probably retard graphitization through the formation of films around the carbide particles. A consideration of the effect of composition must also include minor or gaseous constituents which are

not ordinarily shown in chemical analyses. Hydrogen was said to retard the rate of carbon diffusion in iron, hence to retard graphitization. Oxygen, coming from the melt, may affect the rate of carbide decomposition, but no one knows much about this.

The size and distribution of temper carbon nodules greatly influence the time required for malleabilization. Widely spaced nodules mean that carbon must migrate long distances before precipitating as graphite and, conversely, closely spaced nuclei decrease the time required for diffusion. Factors influencing the number of temper carbon nodules are imperfectly understood, but the subject is an important one to producers of malleable iron.

CHARLES H. JUNGE, research metallurgist of National Malleable & Steel Castings Co., in his paper on "The Suppression of Graphitization by Supercooling" described the freezing of cast iron as a sorting-out process analogous to separating a shuffled deck of cards into piles according to color. At high temperatures (liquid) both iron and carbon atoms are in a comparatively violent state of agitation, but as the metal starts to freeze, the tendency is for carbon atoms to break any chemical bonds holding them to iron as a carbide and separate and precipitate as graphite. Such separation requires time and, if freezing is rapid, it may be prevented. Decreasing temperature finally forces the melt to solidify, and even though the inherent desire of the alloys is to become a mixture of solid iron and graphite, it will find it easier to become solid iron and cementite (iron carbide). The author implied that any cast iron containing eutectic carbide must have been subjected to a certain amount of supercooling.

C. H. LORIG and M. L. SAMUELS, metallurgists at Battelle Memorial Institute, reported on "Some Effects of Hydrogen on the Time of Malleabilization", wherein they discussed primarily the effect of hydrogen on nucleus formation. They compared the time required for malleableizing irons supersaturated with hydrogen, irons from which the hydrogen had been removed by preliminary low temperature treatments, and others containing hydrogen to the extent absorbed during conventional melting.

The response to both first stage malleabilization at, say, 1800° F. (the decomposition of massive cementite) and second stage malleabilization below A_1, or 1400° F. (the decomposition of remaining pearlite) was greatly increased by a low temperature pre-treatment consisting of holding the white iron castings at 600° F. for 8 hr. If so pre-treated, specimens of "quick malleable", taken from melts saturated with hydrogen, completed the second stage graphitization during cooling rates as high as 570° F. per hr. through the range from 1450 to 1200° F. The same material not sub-

Continuous Hearth Furnace for Annealing Malleable Iron. Heated by gas fired radiant tubes and equipped with atmosphere control. Courtesy Surface Combustion Corp.

jected to low temperature pre-treatment (which presumably drives off hydrogen) showed residual pearlite after being cooled at a slow rate of 50° F. per hr. The effect of the low temperature pre-treatments on shortening the malleableizing cycle was attributed to a vastly increased number of graphite crystallization centers.

Since the melts saturated with hydrogen, which were not subjected to low temperature pre-treatment, did not graphitize any faster it was concluded that the mere presence or absence of hydrogen did not afford an explanation for the difference. Nuclei, upon which graphite nodules form subsequently, seem to be created by the *escape* of hydrogen during the holding period at low temperature.

W. D. McMillan, metallurgist, McCormick Works of International Harvester Co., (in "The Effect of Composition on the Annealing of White Cast Iron") showed the importance of silicon content in reducing the time for first stage malleableizing. Irons containing 1% Si required 24 hr. at 1700° F., whereas a 1.70% Si iron was fully graphitized after 3 hr. The conclusions simply affirm what has long been known; unfortunately advantage cannot be taken of the higher silicon contents when large sections are being cast, since the metal will not solidfy as white iron but as mottled iron on account of primary graphitization.

An interesting side-light of Mr. McMillan's paper was that temper carbon nodules become fewer in number and consequently larger in size with continued holding time during first stage annealing (in his experiments at 1700° F.). One iron had an average count of 120 nodules per field after 3 hr. at temperature and only 19 after 7 hr. The mechanism by which, at constant temperature, small nodules precipitate upon larger ones was explained in this way by a discusser: The smaller particles of graphite dissolve in the austenite until a solid solution is formed which is supersaturated with respect to the larger particles. Precipitation then occurs on these larger particles and they grow at the expense of the small nodules. The moral is that a longer holding time than is really necessary for complete first stage annealing may actually be harmful by producing larger temper carbon nodules, which subsequently increase the time necessary for the residual carbon in solution to migrate during the second stage.

The complexity of the atmosphere problem in malleableizing furnaces was discussed by R. J. Cowan of Surface Combustion Corp. ("Atmospheres and the Annealing of Malleable Iron"). The "matrix metal" in a malleable iron casting changes during the annealing cycle from that of a very high carbon to a very low carbon steel; hence, atmosphere control is not as simple as in the heat treatment of simple steels.

Decarburization during first stage malleabilization is very undesirable, because this prolongs the second stage or cooling portion of the cycle. Pearlitic edges or the "picture frame" of white metal around a fully malleableized core was attributed to decarburization in first stage annealing. Oxidation of carbon in the second stage produces tenaceous surface layers of ferrite which decrease machinability. The ideal atmosphere is one which is in equilibrium with the matrix of the casting at all stages of the malleableizing cycle — an ideal which has not been reached in industrial installations.

Three papers were presented at the symposium describing annealing furnaces.

W. R. Bean and W. R. Jaeschke, vice-president and foundry engineer, respectively, of Whiting Corp. gave an account of "Periodic Malleable Annealing Furnaces", stating that over 70% of the malleable iron today is annealed in "periodic" furnaces. These furnaces may be divided into three types: *(a)* Floor-loaded pot type, *(b)* car type pot ovens, and *(c)* muffle ovens. In the first two types of furnaces the castings are placed in pots, with or without packing material. The ratio of castings to oven charge runs about 30 to 40% with packing, and from 40 to 50% when no packing is used. Annealing time per batch ranges from

Car Type of Periodic Annealing Oven. Ready for Unloading. Courtesy Whiting Co.

about 3 to 7 days, and the cost per ton may be as low as $5.50.

Periodic muffle-type ovens consist of one refractory shell inside another. Combustion takes place between the two shells and the inner one is tightly sealed so no prepared protective atmosphere is required. These ovens are especially well adapted for annealing castings which, because of size and shape, cannot easily be packed in pots.

Electric malleableizing furnaces eliminate the need for heavy cast pots and packing material, and this reduces the time required for annealing, according to R. M. Cherry of General Electric's Industrial Dept. Other advantages of "Electric Furnace Annealing of Malleable Iron", as compared with fuel-fired furnaces, include a better control of time-temperature relationships, decrease in the labor needed for loading and unloading the castings, and reduction in the floor space required by about 50%.

Electric annealing furnaces are available for either continuous or periodic operation. One continuous type furnace is equipped with driven hearth rolls which move loaded trays. Another is of the pusher type in which a tray put in at the loading end pushes out another at the exit end. These furnaces, as any continuous machine, require long periods of steady production for economical operation.

One of the most successful of the batch type electric furnaces employs an elevator to raise a loaded car into the heating chamber placed on stilts. The car is sealed at the bottom of this gas-tight furnace and no specially prepared protective atmosphere is necessary. After first stage annealing is completed the elevator lowers the car and its load, which is then shifted over and raised into another furnace at the proper temperature for second stage annealing.

Tunnel Kiln Type of Furnace

R. J. Anderson's paper on "Malleable Annealing in the Dressler or Tunnel-Type Kiln" was read by proxy. The author is general superintendent of Belle City Malleable Iron Co., which operates one furnace of this type. A train of cars, carrying white iron castings packed in pots, is pushed progressively through the kiln. When a car is pushed into the loading end of the kiln, the train pushes one out at the exit end. Sixty-two cars, each one loaded with 4½ to 5 tons, are in the kiln at all times. A "12-car push" per day would give a satisfactory annealing cycle of 124 hr., and a daily production (7 days per week) of 60 tons. The kiln is fired so as to provide a high temperature zone for first stage malleabilization near the loading end, and a lower temperature region for second stage malleabilization toward the the exit end. These furnaces are obviously suitable only for large tonnage production and, especially, for continuous operation. There are about nine of the kilns in operation in this country at present.

J. H. Lansing, shop practice engineer of the Malleable Founders' Society, presented a short paper on "Temperature Control of Graphitizing Furnaces", in which he traced the development of methods for accurate temperature control. Modern malleable iron shops may use indicating pyrometers with the firemen recording hourly readings. These data can be plotted in the form of a time-temperature curve so as to assist in interpreting irregularities in annealing results. Automatic multiple recorders are generally preferable for their permanent record.

Duncan P. Forbes, president of Gunite Foundries Corp. and president-elect of American Foundrymen's Asso., discussed the production of malleable type irons in which the matrix contains an appreciable amount of combined carbon. His contribution was entitled "Graphitization of Arrested Anneal Malleable Iron". The principles governing first stage malleabilization of such irons are identical with those of regular malleable compositions but, in one method, the second stage anneal is modified so as to obtain certain desired properties. In another method a fully malleableized casting is reheated above the critical range to place some combined carbon in the matrix. Following either method of obtaining an austenitic matrix, the casting can be quenched, air cooled, or slow cooled according to the properties needed.

Alloying elements may be judiciously chosen which sometimes permit the desired structures to be obtained without resorting to a rapid cool. This enables the founder to malleableize small batches of the special product along with regular malleable without interrupting the annealing cycle.

Nomenclature, as in the case of so many new metallurgical products or operations, is confusing to those unfamiliar with this particular field. A malleable type of iron (one containing temper carbon nodules) may have a matrix consisting of almost any of the various austenite decomposition products, and yet be referred to as "pearlitic malleable".

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Stress-Strain Relationships in the Drawing of Metals

SINCE it has been established in an article published in METAL PROGRESS last month ("Wedge-Draw Test for Measuring Drawability") that a test has been devised which closely simulates conditions during the actual operation of drawing a cylindrical cup, this further analysis of physical conditions existing during deep drawing will be based on a study of the experimental results. Figure 1 shows the loading conditions on a coupon cut from 0.051-in. sheet being drawn through the wedge-draw die. The terminology and vector relationships are shown at the left. P_t, the tension load on the coupon, is the only force which can be readily measured. P_c, the compressive load acting on the sides of the coupon, can be computed by simple geometry from P_t, neglecting friction. The diagram at the right of Fig. 1 shows the variation of P_t and P_c as the draw progresses. The distance x is the extent of inward (longitudinal) travel of the outer edge of the coupon.

At any point in the draw the compressive stress f_c is distributed along the edge of the blank in a non-uniform manner, as indicated, and this distribution changes as the draw progresses. However, it is readily possible to compute the *average* value of the compressive stress, $f_{c(ave.)}$ from the total compressive load P_c. As the draw progresses the area to which P_c is applied decreases, so that $f_{c(ave.)}$ increases throughout the draw, reaching values of the order of 100,000 psi. toward the end! It does not go to infinity because P_t, which basically produces the compressive force, drops to zero at the end of the stroke. Changes of thickness in the coupon also affect the average stress $f_{c(ave.)}$.

A typical distribution curve of compressive strain ε_c is also shown in Fig. 1. The ε_c curve remains similar in *character* (though the unit strains increase in magnitude from moment to moment throughout the draw) because it also is determined by geometrical conditions.

In Fig. 1 the largest strain (unit deformation ε_c) is opposite the smallest stress (unit load f_c) at the throat of the wedge. This seems anomalous. But consider the movement inward during an elementary pull through the die. During longitudinal movement dx the wedge sides are forced inward parallel to their original location; movement dy is the same in magnitude at all points. However the ratio $\frac{dy}{Y}$ (or strain ε_c) is greatest at the throat, where the width Y obviously is least. Figure 2 shows the wedge with additional stress and strain elements depicted for any location in the draw. In addition to the approximate distribution of f_c, there is also shown the distribution curve of tensile stress f_t. The latter is a maximum at the throat, where it is equal

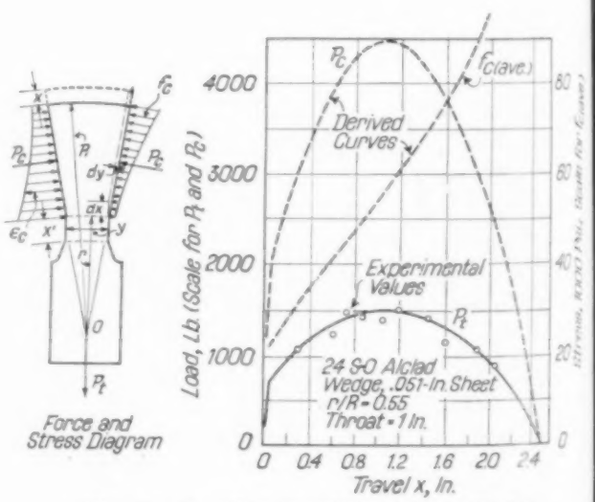


Fig. 1 — Loading Conditions in a Wedge Coupon During the Drawing Operation

to P_t (throat area). From the throat outward toward the blank edge it decreases, due not only to increase in the cross-sectional area, but also to decrease in the effective value of the tensile load from which it is derived; the latter decreases with distance outward from the throat, because at any point it is only sufficient to pull the material *beyond* it.

Since the greatest deformations occur at the throat of the wedge, the variation of stresses and strains at that point as the draw progresses are of greatest significance. Figure 3 shows this variation in the stresses at the throat, plotted as a function of the travel x' of the end of the coupon which is gripped by the pulling device. (x' is equivalent to the punch travel in the actual drawing of a cup.)

The tensile stress f_t at the throat rises to a maximum a little before mid-stroke, and thereafter decreases as the amount of material to be pulled through the wedge decreases. (In this regard it of course reflects the shape of the curve of P_t, the tension load on the coupon in Fig. 1.)

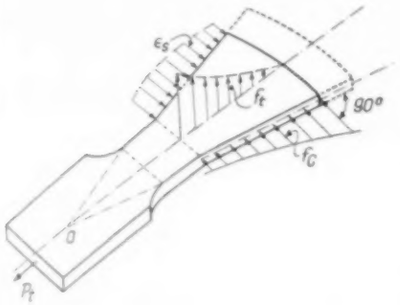


Fig. 2 — Stress and Shear Strain Diagram at Any Moment During the Draw, Indicating High Shear Strain at Throat of Wedge

The curve of f_c, the compressive stress at the throat, shown in Fig. 3, was computed from the average compressive stress, $f_{c(ave.)}$, which, as has already been pointed out, can readily be derived from P_t and the geometry of the wedge. To obtain f_c *at the throat*, it is necessary to make a computation based on the theory of constant flow stress and on the observed deformations at the throat. Like $f_{c(ave.)}$, the compressive stress f_c at the throat rises as the draw progresses, reaching a maximum value at the end of the wedge-draw test.

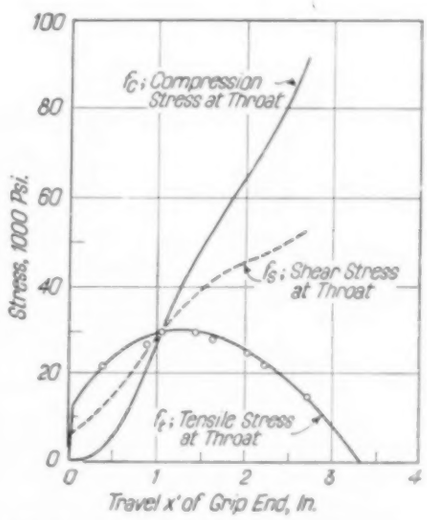


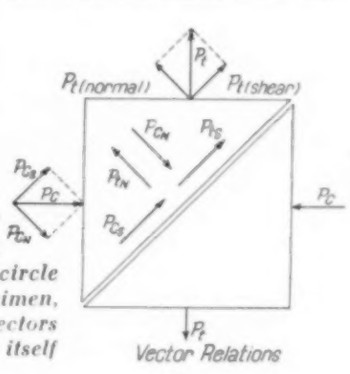
Fig. 3 — Size of Tensile, Compression and Shear Stresses at Throat of Wedge as Test Piece is Drawn Through the Die

The deformation of the metal at the throat takes place under combined tension and compression, a condition that produces tremendously high deformation somewhat analogous to extrusion and wire drawing. As an example, a drawn 24S-O alclad cup has been found to have a tensile deformation of 110% in its flange just outside of the draw radius — an elongation over nine times the guaranteed minimum under simple tension!

Combined Stresses in Action

The key to the phenomena described above appears to lie in the fact that combined compressive and tensile stresses, acting at 90° to one another, produce shear forces $P_{c(shear)}$ and $P_{t(shear)}$ which are additive along the diagonal or shear plane (see Fig. 4). This stress condition is commonly represented by the Mohr's circle diagram. If tension and compression forces are equal, the combined shear stress is double that which would be produced by either acting separately.

At the same time, the components of the forces $P_{c(normal)}$ and $P_{t(normal)}$ normal to the 45° shear plane cancel out, and there is no tendency for the material to separate normal to this plane. If the compressive stress is increased to a value greater than the tensile stress, the total shear stress is increased still more, while the net normal component assumes a direction which presses the material *together* along the shear plane, instead of tending to pull it apart. Meanwhile the separational tendency along the direction of the tensile load P_t has remained constant, since P_t is constant. The net result of increasing compressive forces



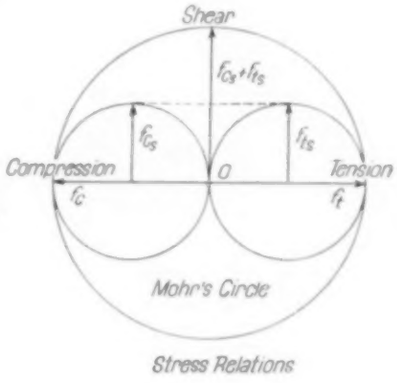


Fig. 4 — Vector Relations and "Mohr's Circle" (Stress Relations) for Combined Tension and Compression. Since the angles in Mohr's circle represent twice the angles in the actual specimen, the 180° displacement between f_c and f_t vectors represents a 90° displacement in the part itself

is that the shear stresses continue to increase along the diagonal planes, but the *separational* stresses are always equal to, or less than, their original values due to the tensile force acting alone. From this point onward, any failure which occurs must be a shear failure.

The above reasoning was applied to the data obtained from the wedge tests, and the internal shearing stresses calculated. The curve marked f_s in Fig. 3 represents the calculated shear in a plane normal to the top and bottom surfaces of the sheet and at 45° to the direction of tensile pull (the cross-hatched surface on Cube *A* (Fig. 5). Figure 5 shows the shear stresses f_s from Fig. 3, as well as f'_s and f''_s acting along the two other 45° planes through the elementary cube.

It is to be noted that only the plane shown in Cube *A* sustains a condition corresponding to Fig. 4, wherein f_c and f_t are combined; hence, only in this case does the shear stress f_s rise to relatively high values. Figure 3 shows that with a maximum *tensile* stress f_t of only 29,000 psi., when the test piece has been drawn about 1¼ in., the shear stress f_s is 35,000 psi. If the tensile stress were acting alone, without side compression, the shear stress on the 45° plane would be only $\frac{1}{2}f_t = 14{,}500$ psi.; to bring it up to its actual value of 35,000 psi. would require a simple tensile stress equal to $2 \times 35{,}000 = 70{,}000$ psi., which is far above the ultimate strength of the material (35,000 psi., when tested under the most favorable conditions).

Despite the fact that toward the end of the draw the tensile stress f_t rapidly decreases toward zero, the shear stress f_s remains at a high value. The reason is that an increasingly great component is being contributed by the compressive stress f_c, which continues to rise, as already shown in Fig. 3.

In the case of f'_s and f''_s (planes shown in Cubes B and C of Fig. 5) combined stress is not present (neglecting the hold-down pressure, which will be discussed later). Since f'_s is a shear component of the compressive stress f_c alone, it increases throughout along with f_c. It acts in such a direction as to tend to increase the thickness. The other shear stress f''_s is a shear component of the tensile stress f_t alone, and so follows the same curve, passing through a maximum and dropping to zero toward the end of the stroke. This component opposes f'_s and tends to *thin* the material.

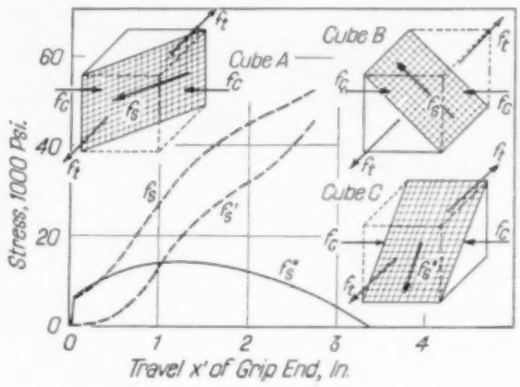


Fig. 5 — Sketches Showing Origin of the Three Coordinate Shearing Stresses on the Elementary Cube, and the Variation in Their Magnitude at the Throat of the Wedge During the Draw

The net effect on thickness of these two opposing forces is given by the solid curve f'_s-f''_s, Fig. 6, which compares very well with the measured thicknesses shown as curve *t*. In the early portion of the stroke f''_s predominates, with a slight thinning tendency. Before mid-stroke the two balance out to give a thickness unchanged from the nominal gage, and at the end of the stroke the thickening tendency greatly predominates over the thinning, which drops toward zero. This is readily observable in practical drawn parts, and agreement between calculated and actual thickness would seem to corroborate the correctness of the calculations and theoretical assumptions.

Hold-Down Load — The compressive stresses tend to be relieved by buckling of the wedge (or the flange of the blank in an actual drawing operation). To prevent this a cover is provided in the wedge die, held down with a considerable force in a compression testing machine, thus simulating the action of the hold-down ram acting on the draw ring in a double action press. This hold-down force adds another component which should be shown as a vertical stress acting on each elementary cube in Fig. 5. The shear component of this vertical stress is usually of little importance relative to the other stresses, but if very high hold-down pressures have to be used to prevent wrinkling, it becomes an appreciable factor toward the end of the draw when the area of material carrying the total load becomes so small as to increase the unit stress greatly. The hold-down load then offers a decided opposition to the thickening action which tends to occur at the end of the stroke and sometimes completely arrests this tendency.

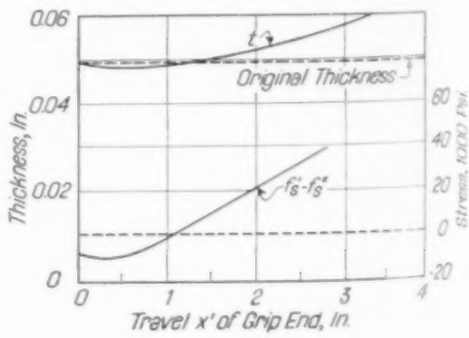


Fig. 6 — Resultant of f'_s-f''_s, Throughout the Wedge-Draw Test, Correlates Well With Thickness t of Piece at Throat During the Test

GROUP 4 .025 2450 ALC. WITH GRAIN
GROUP 5 .025 2450 ALC. ACROSS GRAIN
GROUP 6 .032 2450 ALC. WITH GRAIN
6" CONTROL WEDGE
GROUP 3 .032 2450 ALC. WITH GRAIN
GROUP 1 .051 2450 ALC. WITH GRAIN

Fig. 7 — Wedge of 24S-O and 24S-W at Limiting r: R Ratios. Specimen 17 failed due to excessive hold-down load on the cover plate; specimen 15 of same material and dimension, but more lightly held, drew successfully

Also, the vertical hold-down load acts as a compressive stress to combine with the tensile load f_t along the shear plane in Cube C, Fig. 5, and tends to increase the shear f''_s. This in turn gives a higher shear along this plane relative to the separational stress f_t and contributes to the high deformation obtainable in the direction of the tensile load at the latter part of the draw.

The phenomena associated with high hold-down pressure are more likely to occur with thin than with thick materials, since the latter have less tendency to wrinkle under the sidewise compressive stresses and so require less hold-down pressure.

If hold-down pressures become excessive, the tendency to help matters by the "extruding" action may be counteracted by the heavy friction load imposed on the material still in the wedge. This effect is especially pronounced with light gages, as may be seen in Table I in the article last month, which shows better limiting *r: R* ratios for thick than for thin material. Specimen 17 in Fig. 7 shows failure in a 24S-O alclad wedge, 0.051 in. thick, when a relatively heavy hold-down pressure was used. Excessive pressures will therefore raise the critical *r: R* ratio.

The thickening tendency at the end of the stroke is concretely demonstrated by the rise in hold-down load as the wedge is pulled through, sometimes observed to be as much as 75%.

The Modes of Failure in the Drawing Operation — If in Fig. 3 the curve of f_t, the tensile stress required to pull the material through the wedge, rises above the ultimate strength of the material, the wedge will fail in tension somewhere in the narrowed portion that has come past the throat. (It should be noted that this ultimate strength approaches the "true" ultimate value for the material; that is, the stress figured on the true area just before failure, and is therefore higher than the conventional value from tension test results.) This condition will occur if the wedge angle is made too acute, or the length to be drawn is too great, which in turn corresponds in practice to an attempt to draw a cup too small in diameter from too large a blank — in other words, to attain too low an *r: R* ratio.

If the *r: R* ratio is above this critical value, the maximum on the curve of tensile stress versus travel will be safely under the value representing the ultimate tensile strength of the material and no tensile failure will occur. However, at some later portion of the stroke the maximum *shearing* stress may exceed the ultimate strength of the material in shear, and shear failure will occur. This is shown in Fig. 7, wedge 6, and more clearly in Fig. 8. Figure 9 illustrates the same type of occurrence in a drawn cup. Thus, a material to have good deep drawing characteristics or drawability must pass a severe reduction (low *r: R* ratio) without failing in tension at the draw radius or cup bottom, and also must not shear in the wedge area or flange. A study of the wedge tests of 24S-T illustrated in Fig. 6 of last month's article would lead one to anticipate the results photographed in Fig. 9, and indicates that the wedge

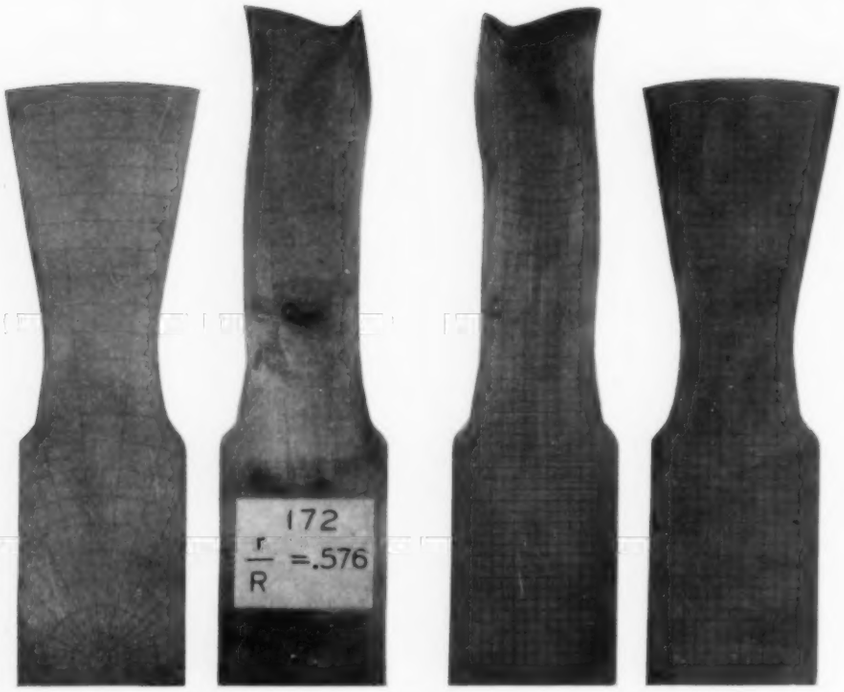


Fig. 8 — Slippage Plane Developed Near End of Stroke on Wedge of 52S-½H. Outermost views are top and bottom of original test piece, one with polar and one with rectangular coordinates; inner pair are respective views after test

test successfully duplicates the conditions of failure met during drawing operations in production.

Examination of the shear failure in specimens such as No. 6, Fig. 7, shows that such failure always occurred on the 45° plane (see also Fig. 8). A similar phenomenon is, of course, well known in the Lüder lines commonly observed in simple tension tests, but in the present case it is evidently the result of the shear from *combined* stresses. The actual distortion of the grid lines across the slippage plane is worthy of a good deal more study with reference to the true nature of the phenomena which occur in over-strained crystal structure.

This distortion of the grid lines occurred when the *r:R* ratios approached the critical, but *only* when the critical condition was one of shear failure. A general instability of the material seemed to occur when the sample approached failure. Until this time is reached, the grid pattern remains fairly regular. One of a series of tests on 52S-½H, for instance (Fig. 8), shows shear at the critical limit when *r:R*= 0.576. Test pieces of this material with *r:R*=0.606 successfully passed, and the grid lines were not nearly so badly distorted.

Table I of the earlier article includes interesting data on the types of failure occurring in all the materials tested, when the *r:R* ratio was critical. All except test pieces made of aluminum in the 24S-O condition failed in shear in the wedge, although they could have been made to fail in tension at the neck had ratios well below the critical been attempted. 24S-O, however, failed in tension in all cases (see Fig. 7), and the grid patterns observed on the coupons were very regular. Little indication of frictional effects at the edges was noticeable.

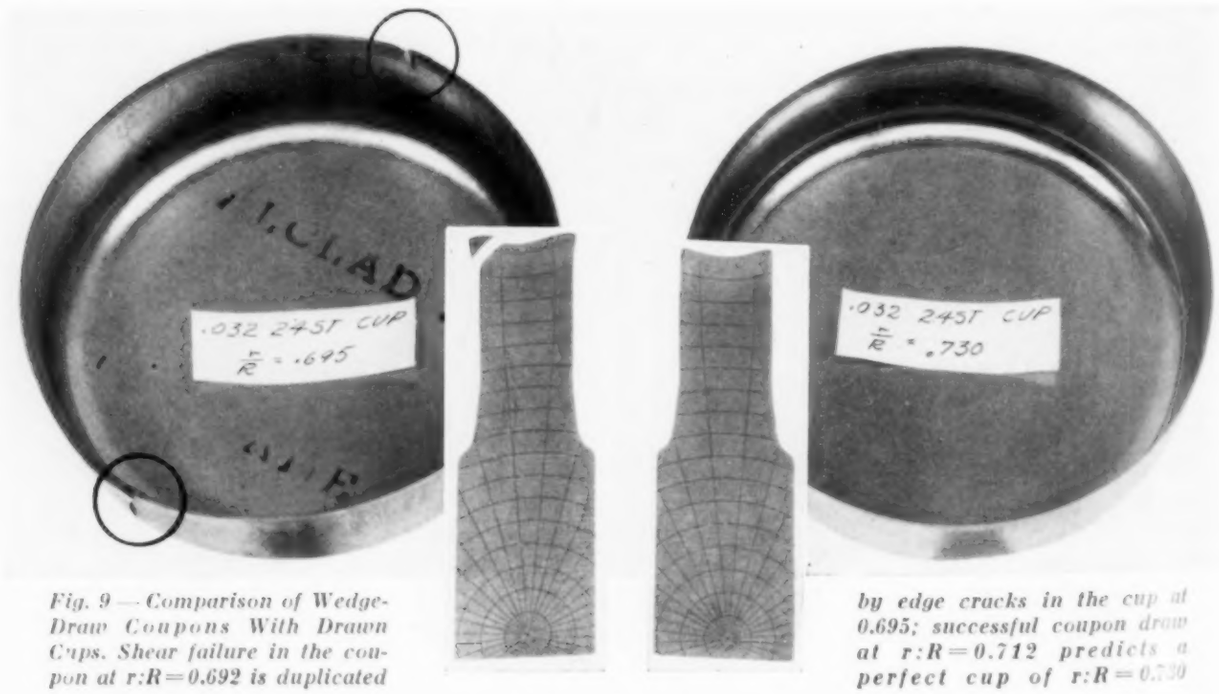


Fig. 9 — Comparison of Wedge-Draw Coupons With Drawn Cups. Shear failure in the coupon at r:R=0.692 is duplicated by edge cracks in the cup at 0.695; successful coupon draw at r:R=0.712 predicts a perfect cup of r:R=0.730

By The Editor

Critical Points

TO CINCINNATI, to tell the Porcelain Enamel Institute that the simplest metallurgical use for idle furnaces (disused for metal signs, and stove and refrigerator bodies) is for annealing to improve machinability of bars, disks and forgings — a real bottleneck these days, what with the expanded production of alloy steels which steel mills usually ship as rolled. Likewise the work could be done en route from steel mill or forge shop to machine shop, and cause the least back-tracking and delay in transit. Surprised enough to find that a few enamelers had already rebuilt furnaces and installed quenching and straightening equipment and were heat treating tank armor — presumably the most difficult of all heat treating operations. (Or is it really as occult as the military censor would have us believe?) Another is getting ready to heat treat aluminum castings, a job requiring the most accurate temperature control and uniformity....Can we ascribe this adaptability to the excellent equipment available in enameling plants? The furnaces, either box-type or continuous, usually have carborundum muffles, pyrometric control, and equipment for handling light bulky loads rapidly, and thus are already about 500% better than those that made the stuff for the 1914-1918 war. Or is this boldness in entering unrelated technical fields due to the widespread knowledge about the science of metals? In this event the ⚙ can certainly take a bow, and the afore-mentioned hush-hush censor take note....Any man, porcelain enameler or other, who has an idle furnace capable of operating at 1600° F., should write immediately to WALTER HILDORF, metallurgist of Timken Steel & Tube, Canton, Ohio, describing the equipment. He will transmit to War Production Board his recommendations and the Board will allocate the work.

Jobs for Porcelain Enameling Furnaces

OBSERVED that melting of enamel on thin metal is a surface effect; work is light and is in and out of the furnace in a few minutes. On the other hand, heat treatment of metal is a deep effect; cycles are measured in as many hours. Surface Combustion Corp.'s C. CONE, at the same Cincinnati meeting, said that a burner arrangement which is correct for frequent door openings will overheat the front when doors are closed for long periods, so the first thing that has to be done to enameling furnaces is to rearrange burners, frequently installing a half dozen small ones in place of one large one. Next, much heavier loads must be handled, and that can be done either by adopting some sort of car-bottom, or reinforcing the present charging forks. In a typical box-type enameling furnace, 5×12-ft. hearth area, annealing costs are rather high, some quotations for specific jobs being: Annealing small cast hooks, soaking in boxes 3 hr. at 1600° F. and furnace cooling, $15 per ton.

Annealing Cycles for Machinability

Pack annealing 15-ton loads of 37-mm. shot, $30 per ton for the following cycle: 2 hr. at 1450° F., drop to 1350° and hold 12 hr., cool at 30° F. per hr. to 1000° F. (frequent manual adjustment of heat control during cooling means high labor cost). Small tank forgings that require normalizing at 1750° before pack annealing as above will cost $50 per ton....Annealing for machinability is a time-consuming operation, especially if completely spheroidized structure is demanded. WALTER HILDORF said, however, that the important chromium and chromium-molybdenum steels 52100 and 4155 can be machined excellently when the microstructure is moderately

coarse lamellae (Brinell 183 to 212) and this can be achieved in as-rolled bars in the shortest time by a fairly long stay within the Ar_3-Ar_1 range and a *slow* cool to below Ar_1. A very good cycle is: Hold 2 or 3 hr. at 1480° F., cool to 1350 at 50° F. per hr., hold at 1350 for 3 or 4 hr., cool to 1200° F. at 10 or 15° F. per hr., and then in air. The "S" curve (see Oct. 1941 issue, p. 517) shows the logic of this cycle. Cooling just through Ar_1 and holding a long time is the same thing as "transformation to lamellar pearlite at constant sub-critical temperature".

Cosmic Ray Counter for Radiographic Exposure Meter

INTERESTED to find that men at Naval Research Laboratory at Anacostia have turned cosmic rays to metallurgical account. (Doubtless their precise minds revolt at this catch line, a crude approximation to the exact truth.) What they are really doing is using "Geiger-Muller counters" for exposure meters on radiographic film, for scanning an area to discover gross defects in less than 1% of the photographic time, and for measuring the precise quantities of diffracted radiation from atom planes when making an analysis of crystalline structure....A Geiger-Muller counter, as you may know, is a gas-filled tube with cathode and anode so sensitively balanced that a single electron released within it by a quantum of hard radiation will "trigger" a discharge of millions more electrons. For such work as HERBERT FRIEDMAN showed me at Anacostia, the tube must also be *quick*, because while it is discharging it is obviously insensitive to the arrival of a second photo-electron. He uses some counters fast enough for 50,000 discharges per sec.; such a tube misses less than one in a hundred coming along in a stream at random time intervals when the average rate is 500 per sec.....Next the problem is to count that fast! Mechanical counters miss too large a number at only 10 random pulses per sec., and it is almost hopeless to "gear down" the speed that low. The simplest way of counting is electrical; a frequency meter circuit delivers current to a micro-ammeter that is proportional to the number of discharge impulses per second from the counter....Now what's this got to do with exposure meters? Simple enough! Suppose that a heavy casting is to be inspected and the radium (or X-ray tube) is in place and the film attached. Knowing by preliminary experiment that 1,000,000,000 X-ray or gamma ray quanta must get through the metal to blacken 1 sq.cm. of film to correct density, it is only necessary to bring the counter with its 1-sq.cm. window up behind the film. The micro-ammeter pointer then swings over proportionately to the amount of radiation getting through the casting at that spot, and its scale is calibrated for *time* required to count 1,000,000,000 impulses. The correct exposure may be read directly from the meter. In fact, the whole area can be scanned very quickly and the correct exposure for the thickest area determined. In this way all variables in emissivity or voltage of source, in focus-to-film distance, or unknown variation in metal thickness, are automatically taken into account.

How Long Must Steel Be Soaked at Heat?

REMINDED that, prior to the last war, it was a rule-of-thumb that ingots should be forged 3 to 1, at least to one-third the original dimensions, "to make them amenable to heat treatment". Gradually it became evident that a smaller amount of mechanical fragmentation of the original crystals was enough to encourage diffusion and recrystallization; unnecessary hot work was not only costly but in some directions harmful, for it would also squeeze the inter-dendritic segregate into preferred directions and cause such things as "transverse weakness"—that is, poor ductility in directions perpendicular to the principal extension by working. So 1.5 to 1 became acceptable for large forgings. ....Is not the time-honored rule of heating and soaking, usually stated as "1 hr. per in. of section", equally archaic? Except in the case of the largest forgings, where the effect of mechanical work does not penetrate to the center, it appears to be principally a concession to safety in days when the heat treater had a vague idea of the temperature within his charge. In these days when one can put heat rapidly and uniformly where he wants it by vigorously circulating a hot protective atmosphere, and can measure the temperature by a thermocouple placed centrally in even a big load, why the "1 hr. per in."? Time at heat is rather a function of the job to be done there, and should be measured by the original segregation, the degree of homogeneity desired, and the speed at which some sluggish atoms diffuse....QUERY: Note the use of the qualitative term "heat uniformly". Who can define the correct degree of uniformity, quantitatively, in degrees Fahrenheit?

TO THE MEETING of the American Iron & Steel Institute in New York, and found those present quietly proud of achievements of the production men who are driving the entire industry currently at 99.6% of capacity, and at better than 90% of capacity for more than 21 months, "the longest sustained effort in the record of steel making", in the measured words of WALTER TOWER, its president. Electric furnace production during the last 12 months has risen to more than three times the output for any year prior to 1940, with openhearth production of alloy steel at a similar ratio. Hence the importance of alloy conservation, best exemplified by the NE 8000 steels, itself the creation of AISI's Technical Committee on Alloy Steel. (Chairmanned by JOHN MITCHELL, Carnegie-Illinois' metallurgical engineer, 26 of the 28 committeemen are ASMembers.)....National Emergency NE 8000 steels utilize the recoverable alloys in the circulating scrap by adding together the combined effects of a little nickel (0.60% max.), a little chromium (0.60% max.), a little more manganese and silicon than ordinary killed steel requires, and a little molybdenum (0.40% max.). Each alloying element slightly "intensifies" the action of the others, and these excellent new low alloy steels undoubtedly will be found capable of doing most of the jobs the more conventional S.A.E. analyses have worthily done for many years....How the general idea works out in the conservation of nickel is this: Of the nickel now going into steels of the 3000 and 4000 series, 30 to 35% eventually finds itself in scrap. Of this nickel considerably less than half has so far been recovered; although the metal does not slag off, the scrap has been melted into steels where the residual nickel is not counted as of value. This nickel so wasted will make as many tons of NE 8000 steels, most of which are substitutable for S.A.E. 3000 and 4000 steels, as the entire 1941 production of S.A.E. 3000 and 4000.

NE 8000 Steels Save Nickel and Chromium

CONSERVATION Note — The steel industry, by the use of such addition agents and deoxidizers as titanium, "alsifer", silico-manganese, silicon and 50% ferrosilicon, has cut its aluminum consumption from 0.69 to 0.56 lb. per ton of ingots. Just a little; but multiply this 2 oz. by 85 million tons of steel and we save 5500 tons of aluminum. Statistical experts can express this in terms of flying fortresses.

READING the news that manicure scissors could no longer use its thimbleful of steel, along with 400 other humble items, and recalled the "Critical Point" made many months ago that war has an insatiable appetite, taking all you have and then demanding more. But if it takes *all* the steel, *all* the copper, *all* the nickel we can possibly make, it is going to take *all* the food, *all* the oil, *all* the cotton, *all* the lumber, *all* the transportation, *all* the manpower of America as well! What this simply means is that we are reaching the limit of our productivity, and must now see to it that nothing is wasted, not even the results of this labor. Hence the reports of ship sinkings on our east coast, 250 by United Press count in the 180-odd days since Pearl Harbor, is bad, bad news only intensified by official condolences from Washington....That same source is as fond of blaming all deficiencies in the shipbuilding program on a supposed shortage of steel plate. There simply must be a whipping boy! But let's look at the record: ARTHUR MCKEE in METAL PROGRESS last December estimated that we could produce 10 million tons of plate per year *plus* at least 5½ million more from mills designed for 24 to 48-in. strip. Suppose we count on only 12 million a year, one million tons of plate a month. Actual deliveries to all government agencies have been creeping steadily up from 750,000 in February to just over one million in May. Of course that's not all for ships; it includes requirements for the Army and Navy, and also for the railroads and new war plants; currently these others are taking 70% of the tonnage. So if ships are paramount to tanks, railroad cars, or synthetic rubber plants, all that is necessary is to tell the right man and plates will swamp the shipyards. Let the manicurists and other humble consumers of the 400 missing steel items reflect that C. E. ADAMS, chief of the Iron and Steel Branch of W.P.B., has assured us that for the fourth successive month, shipments on Maritime Commission orders met the tonnage asked....Of course, it takes more than steel plates to make a cargo ship. American Iron & Steel Institute computes that 4500 tons of ingots are needed to make the hull, machinery and fittings of a Liberty Ship; the industry makes enough steel for 50 of these daily — yet the peak of the shipbuilding program is four per day in 1943. Shipways, engine plants, workmen and managers *(Cont. on p. 869)*

Steel Plate Not Holding Back the Shipbuilders

Application of Controlled Atmospheres to Heat Treating

By C. E. Peck
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THE DEVELOPMENT and application of separately produced controlled atmospheres has grown rapidly for several years. Controlled atmospheres are now an important component in the great majority of heat treating processes where quality control and uniformity of product are required. The scope of the present article is limited to a brief discussion of controlled atmospheres produced in separate equipment, as distinguished from the furnace equipment used in the heat treating process. Atmospheres produced from fuel gas sources and from anhydrous ammonia will be described.

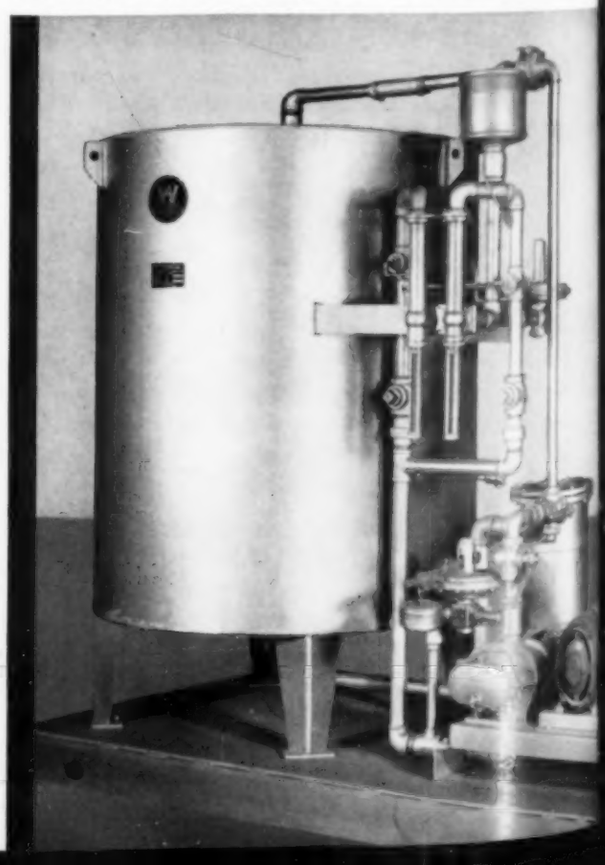
The types of controlled atmospheres produced from commercially available fuel gases and also from anhydrous ammonia are summarized at the top of the data sheet, page 815. The description used and the assignment of a number to each of the principal classes of controlled atmospheres is for reference and identification throughout the remainder of this article. The relatively large difference in cost between the various atmospheres produced from fuel gases (No. 1 to 5) and those produced from anhydrous ammonia (No. 6 to 8) has resulted in a much wider application of the former.

The various component functional equipments required to produce the atmospheres described in the table may be summarized as:

Equipment A; controlled atmosphere generator (exothermic or unheated type). An insulated refractory lined combustion chamber is filled with suitable catalyst and fired at one end by means of a pre-mix burner. The gas flows through a ratio control device which meters the gas and air; flow of these components is indicated on flowmeters. A mixing pump moves air and gas to the burner and on through the combustion unit. The gases from the exit side are cooled down to within 10° F. of the cooling water that is available by means of an enclosed surface condenser and the resultant moisture is separated and drained.

Equipment B; controlled atmosphere generator (endothermic or heated type). This equipment is same as Equipment A except that the combustion chamber consists of a heated

Fig. 1 — Generator Fed With Gas-Air Mixtures so R That Outside Heat Must Be Supplied to Complete the Re tion. Capacity 1000 cu.ft. per hr. of gas suitable for h hardening tool and alloy steels without decarburiz



Prepared Atmospheres

By C. E. Peck, Westinghouse Electric & Mfg. Co.

Composition and Cost of Typical Controlled Atmospheres

Mark	Description	Air-Gas Ratio	Approximate Composition						Dew Point	Gas for M Cu.Ft. Atmosphere	Cost per M Cu.Ft. Atmosphere	Nature of Atmosphere
			N_2	CO	CO_2	H_2	CH_4	O_2				
No. 1	Completely burned fuel	10:1 *(a)*	89.0	0.5	10.0	0.5	0.0	0.0	*(b)*	115 *(c)*	$0.08 *(d)*	Non-combustible; slightly reducing
No. 2	Partially cracked fuel (Self propelled)	6:1 *(a)*	69.0	10.0	5.0	15.0	1.0	0.0	*(b)*	145 *(c)*	$0.10 *(d)*	Combustible; toxic; medium reducing
No. 3	Completely reacted fuel (Auxiliary heat needed)	2.75:1 *(a)*	41.7	19.0	0.0	38.0	1.3	0.0	−10° F.	200 *(c)*	$0.18 to 0.25 *(e)*	Combustible; toxic; most reducing
No. 4	No. 1 scrubbed of CO_2 and H_2O	10:1 *(a)*	98.0	1.0	0.0	1.0	0.0	0.0	−50° F.	125 *(c)*	$0.20 to 0.40 *(e)*	Non-combustible; inert
No. 5	No. 2 scrubbed of CO_2 and H_2O	6:1 *(a)*	72.0	11.0	0.0	16.0	1.0	0.0	−50° F.	150 *(c)*	$0.22 to 0.42 *(e)*	Combustible; toxic; reducing
No. 6	Dissociated ammonia	No air	25.0	0.0	0.0	75.0	0.0	0.0	−60° F.	22.2 lb. NH_3	$2.00 to 4.00 *(f)*	Combustible; reducing
No. 7	No. 6 completely burned	1.88:1 *(g)*	99.0	0.0	0.0	1.0	0.0	0.0	*(b)*	13.7 lb. NH_3	$1.20 to 2.40 *(f)*	Non-combustible; inert
No. 8	No. 6 partially burned	1.25:1 *(g)*	80.0	0.0	0.0	20.0	0.0	0.0	*(b)*	14.9 lb. NH_3	$1.30 to 2.60 *(f)*	Combustible; slightly reducing

(a) Air-gas ratios are representative for natural gas containing practically nothing but methane. For high hydrogen city gas, ratios are about 50% of values given; for city gas with medium hydrogen and high CO, ratios are about 40% of values given. For propane, ratios are approximately twice the values given in the table, and for butane about three times.

(b) Dew points correspond to room temperatures unless auxiliary drying equipment is added. Dew point may be reduced to 40° F. by simple refrigeration equipment; to −50° F. or less by use of absorbent towers.

(c) Values are in cu.ft. for high methane natural gas. For various types of manufactured city gas, double the values given. For propane, requirements are half of values given, and for butane one third.

(d) Costs figured on raw natural gas at 50¢ per M cu.ft., electricity at 1¢ per kw-hr., water at 5¢ per M gal. Use of city gas usually doubles the cost figures given.

(e) Low value when reactivating moisture absorbent with steam; high value when using electrical heat.

(f) Costs based on 7¢ per lb. NH_3 in tank car lots and 16¢ per lb. for cylinder quantities. Electricity for dissociation at 1¢ per kw-hr.

(g) Dissociated ammonia.

Atmospheres Suitable for Heat Treatment of Different Metals

Material Processed	Process	Temperature Range, °F.	Time Cycle ("Long" if Over 2 Hr.)	Required Surface	Atmospheres Which Will Give Desired Results	Atmospheres Commonly Used
		Bright or Clean Annealing				
Low carbon steels	Anneal	1200 to 1350	Long	Bright	2, 4, 5, 6, 7, 8	2
Medium carbon steels	Anneal	1200 to 1450	Long	Bright	4, 5, 6, 7, 8	4
	Anneal (no decarburization)					
High carbon steels	Anneal	1200 to 1450	Long	Bright	4, 5, 6, 7, 8	4
	Anneal (no decarburization)					
Alloy steels, medium & high carbon	Anneal	1300 to 1600	Long	Bright or clean	4, 5, 6, 7, 8	4, 5
	Anneal (no decarburization)					
High speed toolsteels including molybdenum high speeds	Anneal	1400 to 1600	Long	Bright or clean	4, 5, 6, 7, 8	4
	Anneal (no decarburization)					
Stainless steels, chromium & nickel-chromium	Anneal	1800 to 2100	Short and long	Bright	6	6
High silicon steel, electrical sheet	Anneal	1900 to 2000	Long	Clean	4, 7	4, 7
Copper	Anneal	400 to 1200	Long or short	Bright	1	1
Various brasses	Anneal	800 to 1350	Long or short	Clean	1	1
Copper-nickel alloys	Anneal	800 to 1400	Long or short	Bright	4, 7	4
		Automatic Brazing or Soldering Operations				
Low carbon steels	Copper brazing	2050	Short	Bright	2, 3, 5, 6, 8	2
Medium & high carbon steels	Copper brazing (no decarburization)	2050	Short	Bright	3, 5, 6, 8	3
Alloy steels, medium & high carbon	Copper brazing (no decarburization)	2050	Short	Bright	3, 5, 6, 8	3
High carbon, high chromium steels	Copper brazing	2050	Short	Bright	6	6
Stainless steels	Copper brazing	2050	Short	Bright	6	6
Copper or brass	Phos-copper brazing or silver soldering	1500 to 1600	Short	Bright	1	1
		Bright Hardening and Tempering				
Medium carbon steels	Hardening	1400 to 1600	Short	Bright or clean	3, 4, 5, 6, 7, 8	3
High carbon steels	Hardening	1400 to 1800	Short	Bright or clean	3, 4, 5, 6, 7, 8	3
Alloy steels, medium & high carbon	Hardening	1400 to 1800	Short	Bright or clean	3, 4, 5, 6, 7, 8	3
High speed toolsteels, including molybdenum high speeds	Hardening	1800 to 2400	Short	Bright or clean	3, 4, 5, 6, 7, 8	3
All classes of ferrous metals	Tempering or drawing	400 to 1200	Short	Bright or clean	2, 4	2

Helpful "Staff Work"

IN THE BATTLE OF PRODUCTION

All over America, engineers and production men are converting plants to war needs. These men know they can... upon request... get helpful suggestions from us about ways to speed up the working of metals and alloys.

This helpful information has been mobilized into convenient charts, pamphlets and other printed pieces. These tools-in-type range from technical data for engineers to simplified reports on performance of alloys containing Nickel under specific operating conditions.

Here, also, are correlated latest reports from the field about selection, fabrication and uses of ferrous and non-ferrous Nickel Alloys.

And, as further support for your battle of production, we offer personal assistance from members of our technical staff. With recent experience in many plants facing materials difficulties, these men become especially helpful. During wartime, Nickel... and information about Nickel... must go where it best serves the United Nations.

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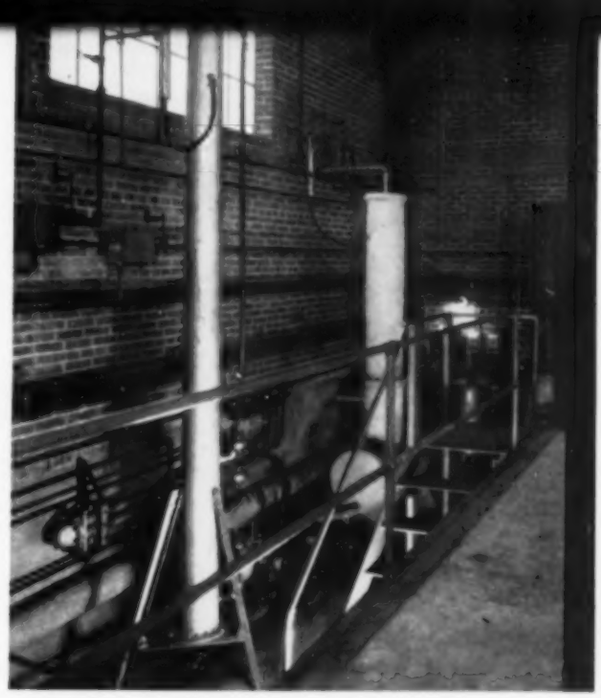


Fig. 2—Tower for Scrubbing CO_2 Out of Prepared Atmospheres, and Auxiliary Equipment for Recovery of Solvent. Dry atmospheres free of CO_2 will bright anneal high carbon and alloy steels without decarburization

catalyst chamber; external heat is required to maintain the air-gas mixture at sufficient temperature for complete reaction of the gas. See Fig. 1, page 814.

Equipment C; carbon dioxide removal system. This is an auxiliary to Equipment A when it is desired to remove the carbon dioxide from the effluent before using it as a controlled atmosphere gas. In it an organic chemical solution (mono-ethanol-amine) is continuously recirculated to absorb the carbon dioxide. The liquid containing the carbon dioxide in solution is reconditioned by heating, which drives off the carbon dioxide gas to waste. A system of pumps and heat interchangers is used for efficient and economical operation. See Fig. 2, above.

Equipment D; for partial removal of moisture. This has many of the elements of a domestic refrigerator, and is mounted in an insulated cabinet. A system of baffled finned coils inside a cabinet cools the gas to about 40° F. and thus reduces its moisture to that corresponding with the dewpoint (see data sheet in October 1941 Reference Issue METAL PROGRESS, page 571). A hermetically sealed refrigerating compressor moves the refrigerant through the cooling coils.

General Applications of Controlled Atmospheres

	SUITABLE APPLICATIONS	UNSUITABLE PROCESSES
No. 1	1. Bright annealing of copper and clean annealing of brass. 2. Inert atmosphere for purging enclosures of explosive or combustible mixtures of gases. 3. Processes requiring inert atmosphere, where CO_2 is not objectionable.	Bright annealing of ferrous metals as a general group, since CO_2 and H_2O act as oxidizing agents. Is highly decarburizing to ferrous metals heated above 1200° F.
No. 2	1. Bright annealing and bright tempering of ferrous metals on short and long heating and cooling cycles. Is usually decarburizing to medium and high carbon steels and alloy steels. 2. Copper brazing of ferrous metals (except stainless steels) where decarburization is not a factor. 3. Brazing of non-ferrous alloys at low to high temperatures where embrittlement caused by reducing properties of gas is not a serious factor. 4. Applications in powder metallurgy requiring moderate reducing action.	Bright hardening of ferrous metals, if prevention of decarburization is a necessary requirement.
No. 3	1. Bright hardening of high carbon steels and alloy steels without oxidation or decarburization. 2. An efficient carrier gas for gas carburizing. 3. Brazing of ferrous metals, particularly those containing high carbon and which permit little or no decarburization. 4. Sintering and powdered metal processes where very high reducing properties are required.	
No. 4	1. Bright hardening and bright annealing of all carbon and alloy steels on either long or short cycles without oxidation or decarburization. 2. Annealing and hardening of high speed toolsteels, such as the molybdenum high speed steels. 3. An atmosphere for annealing high silicon steels. 4. Long cycle annealing of a wide range of straight carbon and alloy steels without oxidation or decarburization.	Processes requiring high reducing properties, such as brazing, because this gas is relatively inert.
No. 5	1. Annealing carbon and alloy steels on long cycles without oxidation or decarburization, particularly for sealed work where gas must overcome decarburizing components generated during the heat treating cycle. 2. Brazing high carbon and alloy steels without decarburization.	
No. 6	1. Bright annealing of stainless steels. 2. Bright hardening of high carbon, high chromium toolsteels. 3. Bright annealing of high carbon steels without decarburization. 4. Brazing of all types of ferrous metals. 5. The only gas which will copper braze stainless steels directly without use of coatings, fluxes, or special brazing alloys. 6. Applications requiring a high hydrogen source costing much less than cylinder hydrogen.	High flammability and high cost compared to fuel gases prevent broader use of this gas for general heat treating and brazing processes.
No. 7	1. Applications as outlined for gas No. 4. Additional drying equipment is required to reduce dewpoints to −50° F. or lower.	Broader use is prevented by higher cost of production compared to cost of gas No. 4.
No. 8	1. Applications listed for gas No. 4.	Broader use prevented by higher cost of production compared to cost of gas No. 5.

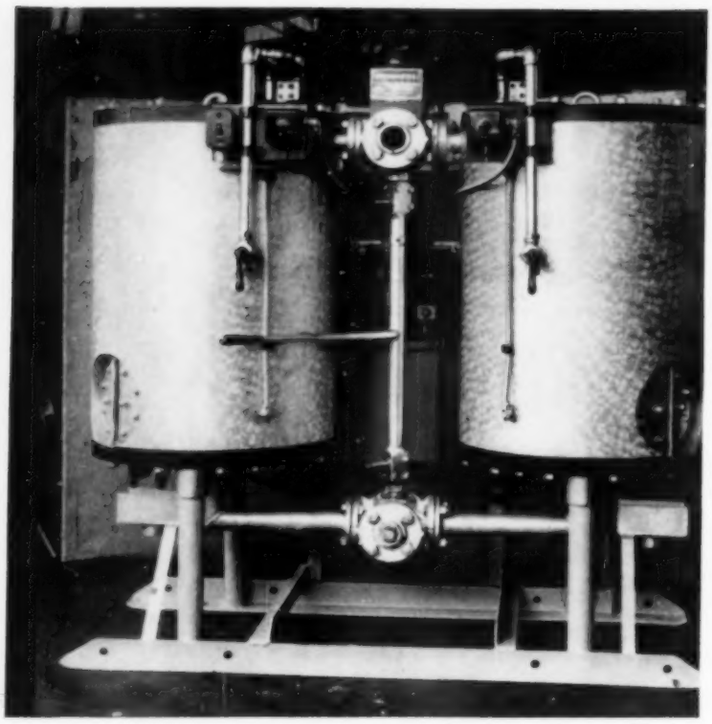


Fig. 3 — Alumina Driers (Dual Arrangement for Alternate Regeneration) for Production of "Bone Dry" Gas — Dewpoint as Low as —75° F. Equipment manufactured by Pittsburgh Lectrodryer Corp.

Equipment E; for complete removal of moisture. A dual tower containing activated alumina absorbs moisture from the controlled atmosphere gas. The purpose of the dual arrangement is to provide continuous gas drying; while one tower is being reactivated by removing the absorbed moisture, its partner is drying the gas prior to use. See Fig. 3 above.

Equipment F; Ammonia Dissociator. An electrically heated catalyst chamber breaks down the anhydrous ammonia to thoroughly dissociated gases.

Equipment G; for dissociating ammonia and burning the gas. The combustion chamber for burning hydrogen to water vapor and its auxiliaries are similar to those in Equipment A. In this case dissociated ammonia is burned instead of fuel gas. See Fig. 4, page 819.

It will now be useful to list the equipment combinations necessary to produce the controlled atmospheres described in Table I.

To produce Atmosphere No. 1, use Equipment A (or A and D) set for complete combustion of the fuel gas.

To produce Atmosphere No. 2, use Equipment A (or A and D) set for partial combustion of the fuel gas.

To produce No. 3, use Equipment B.

To produce Atmosphere No. 4, use Equipment A at gas-air ratio for complete combustion, plus Equipments A, D, and E.

To produce Atmosphere No. 5, use Equipment A as above, plus Equipment C, D and E.

To produce No. 6, use Equipment F.

To produce Atmosphere No. 7, use Equipments F, G, D and E, with burners set for complete combustion.

To produce Atmosphere No. 8, use Equipments F, G, D and E, with burners set for incomplete combustion.

Furnace Equipment to Be Used With Controlled Atmosphere

In general, all furnace equipment must be individually analyzed and designed for the particular application of controlled atmosphere required. Atmosphere furnaces are fabricated to be gas tight. Many schemes are used to minimize the consumption of prepared atmosphere and to insure positive control of atmosphere flow or circulation inside the furnace structure. When fuel fired furnaces are used, radiant tubes or muffles are necessary to keep the products of combustion from mixing with the prepared atmospheres. Electric furnaces of the type using resistors may be used without muffles where other factors in the application permit it.

Separately controlled atmospheres are now being widely applied to a variety of popular types of modern furnace equipment such as pusher, roller hearth, box, bell type, belt conveyor, and elevator furnaces.

In general, before any application of separately controlled atmosphere equipment is made to existing furnace equipment, all factors should be carefully analyzed and the experience of equipment manufacturers fully utilized.

The general applications of different types of controlled atmospheres are summarized in the central portion of the data sheet, page 815. Such statements may be used as a general guide. It is not within the scope of the present article to define individual applications in a detailed manner.

Other tables in the data sheet and on page 817 give further information on applications, but are arranged with the purpose of identifying the use of the different atmospheres with specific classes of materials. These include information on applications of atmospheres when used in furnace brazing as well as in the normal heat treatment processes.

Secondary Copper—

Sources, Amount,

Treatment

OFFICE of Production Management (predecessor of War Production Board) late in 1941 asked the Advisory Committee on Metals and Minerals of National Academy of Sciences to make a study of the secondary copper situation, and the draft was prepared by ERNEST E. THUM, Editor of *Metal Progress*. At the very outset of the investigation into the possibility of putting secondary copper into better use — which is the broad problem of conservation and substitution — it seemed desirable to get some idea as to the volume of metal involved, and its points of consumption. Only meager detailed statistics exist, and those are rather puzzling to interpret. For this reason and, more important, due to the fact that normal channels of trade are entirely disrupted, the available figures take on qualitative significance only.

Refinery Secondary Metal — The United States Bureau of Mines has published, year after year, figures concerning the sources of all our copper, whether mine production, secondary metal, or imported metal. Likewise the American Bureau of Metal Statistics (a private organization) has assembled figures on the consumption of unalloyed copper year by year. For instance, in 1939 we find in the Bureau of Mines figures, in net tons:

Refinery production from domestic ores	704,900
Refinery production from foreign metal	304,600
Refinery production from secondary metal	116,600
Imports of refined copper	16,300
Withdrawn from warehouse stocks	85,500
Total apparent supply of new copper	1,227,900 *(a)*
Less exports of refined copper	396,400
Apparent domestic uses	831,500
Check; American Bureau of Metal Statistics	801,000

The check in the last two lines is almost exact when the period 1935 to 1940 incl. is summarized (see Table I, page 820).

The last column in Table I includes copper derived from two sources: *(a)* Virgin copper from ore, domestic and imported, and *(b)* metal recovered from unalloyed "demolition metal", recovered and re-marketed as unalloyed copper either by copper refineries or by secondary ingot remelters.

No information concerning the *source* of

(a) Total rated capacity of electrolytic refineries is 1,572,000 tons of copper cathodes per year.

4— Combustion Equipment Developed by Westinghouse for Dissociating Ammonia and Partially Burning Gas. Hydrogen content can be regulated from 75% to 5%. Output can be as low as 5% of rated capacity

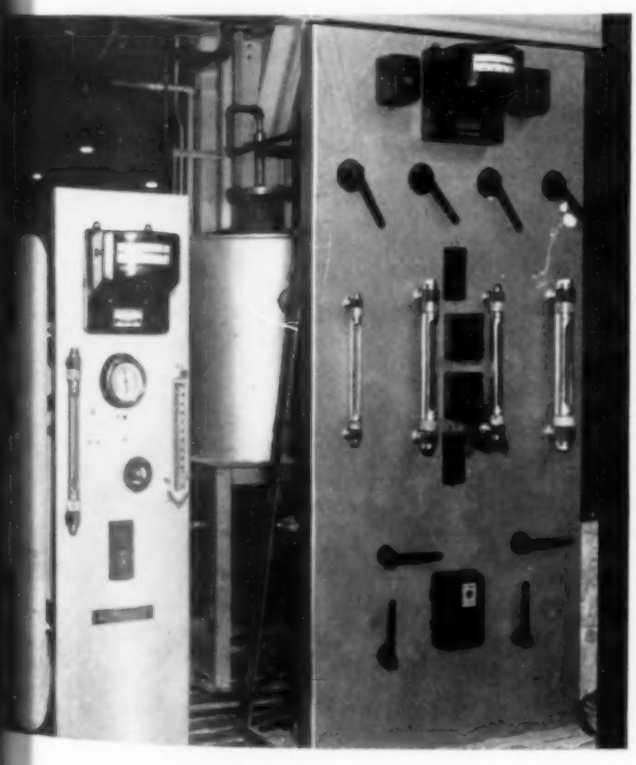


Table I — Source of Copper Available to U. S. Industry (Net Tons)

Year	Figures by Bureau of Mines			American Bureau of Metal Statistics (Consumption)
	New Copper From Secondary Metal	Virgin Copper	Total; Deliveries for Consumption	
1935	148,500	441,300	589,800	574,700
1936	132,900	656,200	789,100	749,000
1937	156,600	694,900	851,500	860,000
1938	92,500	407,000	499,500	608,000
1939	116,600	714,900	831,500	801,000
1940	117,600 *(a)*	1,008,800	1,126,400	1,070,000
Totals	764,700	3,923,100	4,687,800	4,662,700

(a) It is anticipated that this figure will be considerably smaller for 1941.

the secondary metal received by the refineries, as reported by the Bureau of Mines in Column 2 of Table I, is available except by extending some data given for the first time in the 1939 Bureau of Mines report. It would seem that about one third of the metal is "new scrap" or "plant scrap" (that is, clippings, defectives and other plant scrap returned from the wire, plate and bar mills handling unalloyed copper) and two thirds is "old scrap" or "demolition metal" (trolley wire and bare conductivity wire plus other alloyed copper articles withdrawn from use because worn out or obsolete). Under these circumstances, about 50,000 tons of copper a year (300,000 tons for the six-year period) should be deducted from the available copper for use, for it is merely a recirculating load of metal in process. Even when 300,000 tons of copper is deducted from Columns 2 and 4 the check with the last column (total consumed by American industry) probably is as good as can be expected, in view of changes in plant inventories.

Refinery Secondary Metal

Before proceeding, it may be desirable to say something about the treatment of this "refinery secondary" metal. It reaches the copper consuming industry through the eight electrolytic and two furnace refineries in the United States. The principal business of these refineries is to make marketable copper from impure metal derived from the smelting of oxide and sulphide ores. All such refined metal, irrespective of source, reaches the market as metal of high purity, not alloyed nor containing more than very small fractions of 1% of adventitious elements. Thus, "refinery secondary" metal is indistinguishable from refined metal from ore.

Since 1935 this "refinery secondary" has been constantly decreasing in amount, and currently is at an unusually low rate due to the large consumption by remelters of composition ingot. Much of it has come from what is known

Drosses, Very Impure Alloy Scrap, Brasses, and Iron-Contaminated Copper Are Added to the Charge Going to Smelting Furnaces. The copper is collected in the sulphide matte and most of the other elements are slagged or fumed off. Matte is bessemerized (in the vessel shown at right in process of being charged) to "blister" copper, then cast into anodes for electrolytic refining. (Wide World)

to the trade as "No. 1 copper scrap", a grade that is usually pure enough to be charged with the cathodes from the electrolytic refining tanks into the final furnace-refining operation and thence be cast into slabs, bars or billets for rolling mill use. As will be argued at length later, it is believed that this is not the best use for much of this high grade demolition metal. A few hundred tons annually of small ingots intended for foundry use is also made from this metal by the refineries.

Another major class of scrap reaching the refinery is "No. 2 copper" high in lead that is cast into anodes and sent through the electrolytic refining tanks.

Conversion Contracts

Likewise, in the past, a certain amount of refined metal has originated in smelters which have received consignments of drosses,* mattes, speisses, impure and highly alloyed metal, and copper too high in iron for non-ferrous alloying. These metals were received from foundries, scrap wholesalers, and secondary remelters who are unable to convert it by simpler means into salable alloy; very frequently the smelters accept such matte and impure metal on a toll basis, or by "conversion contracts", whereby the vendor receives an equivalent amount of marketable metal in return. Such conversion contracts are now prohibited by the Priorities Board as a means to bring this refined metal under control; impure metal may be sold outright to the smelter, but the result is that little or none of it is now being so transferred.

As will be seen in what follows, the "refinery secondary" metal amounts to about one quarter of the entire recoveries of secondary metal; from what has already been said it will be appreciated that its use and ultimate destination cannot be distinguished from refined metal from newly mined ore. Future trends, as will be shown, will probably be a considerable reduction in refinery receipts of "No. 1 metal" which need only be furnace refined, but a very considerable increase in receipts of low grade metal which must go through the smelting and electrolytic process.

Two problems, therefore, seem to be in need of some detailed study: First, whether the refineries, both furnace refineries and electrolytic refineries, will have sufficient capacity to produce pure copper from expanding mine production and yet absorb more secondary metal which may be expected to appear, and second, the problem of "conversion contracts"—namely, how to restart an increasing flow of impure metal back to the smelters for separation into its components and their conversion into useful form.

Secondary Copper Re-Used by Brass Mills and Non-Ferrous Foundries

Statistics so far quoted apply only to copper from ore, from plant scrap and from high grade demolition metal that reappears as *unalloyed* copper. A very large additional amount of metal from plant scrap and from demolition scrap is re-used as alloy, after first being segregated and remelted by non-ferrous ingot metal producers (the "remelters") and by the brass and bronze manufacturers and the non-ferrous foundry industry. For statistics on this phase of the metallurgical industry we turn to the Bureau of Mines, and find figures from which the last column in the *(Continued on page 872)*

*The normal foundry loss on remelting composition ingot is 4% to dross.

Table II — Distribution of Secondary Copper by Points of Re-Emergence and Nature (New or Old)

Year	Points of Re-Emergence			Total Secondary Copper	Nature of Source		
	Copper in Refinery Secondary	Copper in Alloy Ingot *(a)*	Copper Recovered in Mills and Foundries		From New Scrap	From Old Scrap	% Old Scrap
1935	148,500	75,400	225,000	448,900	87,200	361,700	81
1936	132,900	94,200	257,500	484,600	101,900	382,700	79
1937	156,600	106,800	268,700	532,100	123,200	408,900	77
1938	92,500	55,000	212,300	359,800	92,500	267,300	74
1939	116,600	85,500	297,600	499,700	212,800	286,900	57
1940	117,600	112,000	302,400	532,000	198,200	333,800	63
Totals	764,700	528,900	1,563,500	2,857,100	815,800	2,041,300	

(a) Tonnage of alloy ingot reported to Non-Ferrous Ingot Metal Institute increased by 20%.

By Steel Standardization Group
Bethlehem Steel Co.
Carnegie-Illinois Steel Corp.
Chrysler Corp.
Great Lakes Steel Corp.
Pittsburgh Crucible Steel Co.
Republic Steel Corp.
The Timken Roller Bearing Co.
Steel & Tube Division

Determination of Recalescent Points in Steels

IN THE COURSE of developing standard methods for testing many of the metallurgical characteristics of steels, the Steel Standardization Group (described in "Critical Points" for November 1941) turned its attention to the determination of critical points. Critical point values are given in the literature for a wide variety of steels and have been determined by many different methods but an examination of these data reveals that in nearly all cases either no attention was paid to the rate of temperature change during the test or the investigator merely identified the rate as "fast" or "slow". Since this one factor of rate of temperature change is more important than any of the other variables entering into the accurate determination of transformation points, it was felt that any precise method must be based upon rigid control of this all-important factor.

Fundamentally, the following methods are available:

1. Thermal
   - *(a)* Inverse rate
   - *(b)* Differential
2. Dilatometric
3. Metallographic (by a quenching series)
   - *(a)* Hardness of quenched pieces
4. Electrical
   - *(a)* Electromotive force
   - *(b)* Resistance
   - *(c)* Magnetic

Of these methods the first two — thermal and dilatometric — are more easily applied commercially, while the last two — metallographic and electrical — are probably the more accurate research methods. Of the commercial methods, the dilatometric method is probably the easier to run and yields the most information. This method is, therefore, the approved one for determining critical points.

The A_1 and A_3 critical points of steel are reversible changes of state and hence should occur at specific temperatures under equilibrium conditions. It is realized that the eutectoid transformation in commercial steels is not an invariant reaction, but if only the *beginning* of the change on heating and the *ending* on cooling is considered, the above statement is substantially correct. The well-known hysteresis effect, however, causes divergence in the points when observed at appreciable rates of heating and cooling, and this divergence increases with increase in rate of temperature change. To counteract this hysteresis effect as much as possible, the Ac points should be chosen at the lowest temperature and the Ar points at the highest temperature on the dilatometer record at which detectable change can be discerned.

The following is the method adopted:

Sample — The sample shall be a cylinder taken in such a way that its exact chemistry is known, and either encompasses the entire cross-section of the ingot or is taken from the mid-radius location of the bar or billet.

Heating — The sample must be heated uniformly over its entire length. ("Uniformly" means to a maximum temperature variation of 10° F.) The *rate* of temperature change must be rigidly and automatically controlled in order that results may be reproducible and have any

meaning. The maximum temperature attained and the holding period at that temperature affect the Ar points, making it necessary also to control these variables.

Test Cycle — The following test cycle is recommended:

Heat to 100° F. below the approximate position of Ac_1.

Hold at this temperature 30 min., to attain approximate equilibrium conditions.

Heat at the chosen rate through Ac_3 and on up 20° above.

Heat rapidly to a temperature 150° F. above the observed Ac_3.

Cool rapidly to the observed Ac_3 point plus 20° F.

Cool at the chosen rate to Ar_1—20° F.

Two typical dilation vs. temperature curves run by this test cycle at the rapid rate of temperature change (400° F. per hr.) are shown in Fig. 1. One is for an A 4023 carbon-molybdenum steel and the other is for an A 4068 steel.

Interpretation of Results — In many cases it is necessary to know the critical points at different rates of temperature change. For ordinary heat treating, the Ac_3 point at a rapid rate of heating is desired; for spheroidizing annealing, practically the equilibrium A_1 point is required; for handling large sections, particularly of sluggish analyses, the Ar points at slow rates of cooling are very neces-

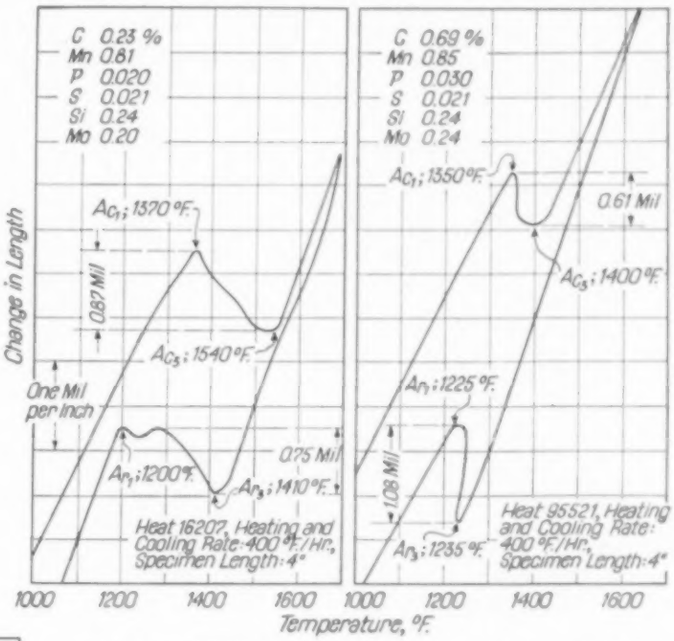


Fig. 1 — Dilation Vs. Temperature Curves for Two Carbon-Molybdenum Steels, Using the Standard Test Cycle and Temperature Change of 400° per Hr.

sary information. The determination of critical points at rigidly controlled rates of temperature change of 400, 100 and 10° F. per hr. is recommended when complete information is desired.

The critical point values obtained at various rates are best presented by plotting the logarithm of the rate of temperature change in °F. per hr. versus the temperature of the transformation, and drawing the best straight line through the plotted values. Typical examples of this method of presentation for the same steels as shown in Fig. 1 are shown in Fig. 2. From such plots, the critical points at any desired rate of temperature change may be read directly. The point of intersection of the lines for the same transformation (for example, the Ac_1 and Ar_1) is a very good approximation of the equilibrium transformation temperature. It

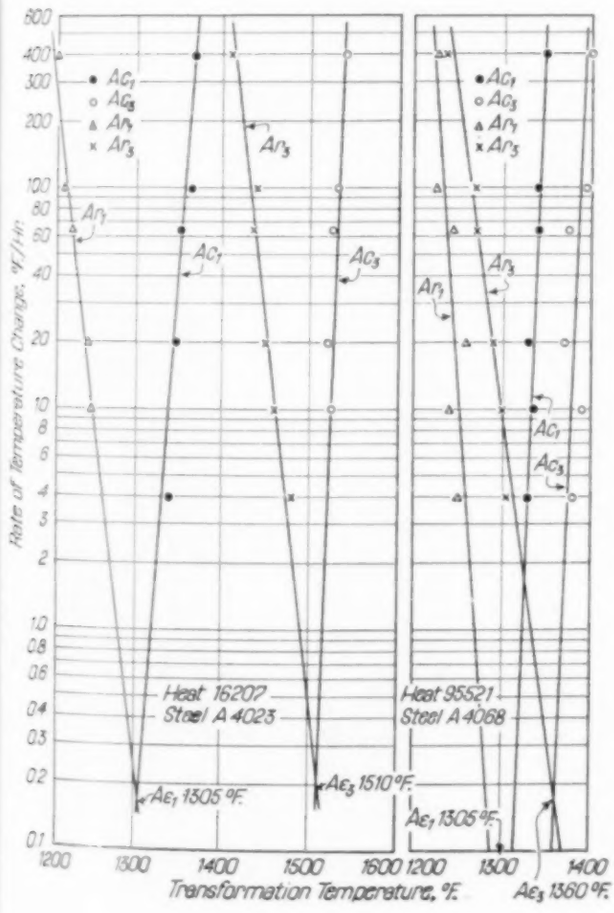


Fig. 2 — Semi-Logarithmic Charts Showing Critical Points of A 4023 and A 4068 Steels as Determined at Different Rates of Temperature Change, and Extrapolation for Approximate Equilibrium

is true that such curves should theoretically approach each other asymptotically at zero rates, but, if the straight lines intersect at or below 1° F. per hr., the straight line assumption is deemed sufficiently accurate.

As examples of this standard method of determining critical points and presentation of results, determinations were run at several different rates ranging from 400 to 4° F. per hr. on the two steels whose compositions are given in Fig. 1. The resulting critical points at each rate were plotted on semi-log coordinates and are shown in Fig. 2 at left and right, respectively. Inspection of the results indicates that in the case of the low carbon heat, the maximum deviation of any point from the best straight line is 8° F. while high carbon heat has a maximum deviation of 12° F. In both cases the effect of rate of temperature change on the positions of the critical points can be clearly seen. Extrapolation of the best straight lines to intersection produced approximate equilibrium A_1 and A_3 values of 1305° F. and 1510° F., respectively, for the low carbon heat and 1305° F. and 1360° F., respectively, for the high carbon heat. All intersections occurred at rates of 0.2° F. per hr. or less, thus checking the validity of the work.

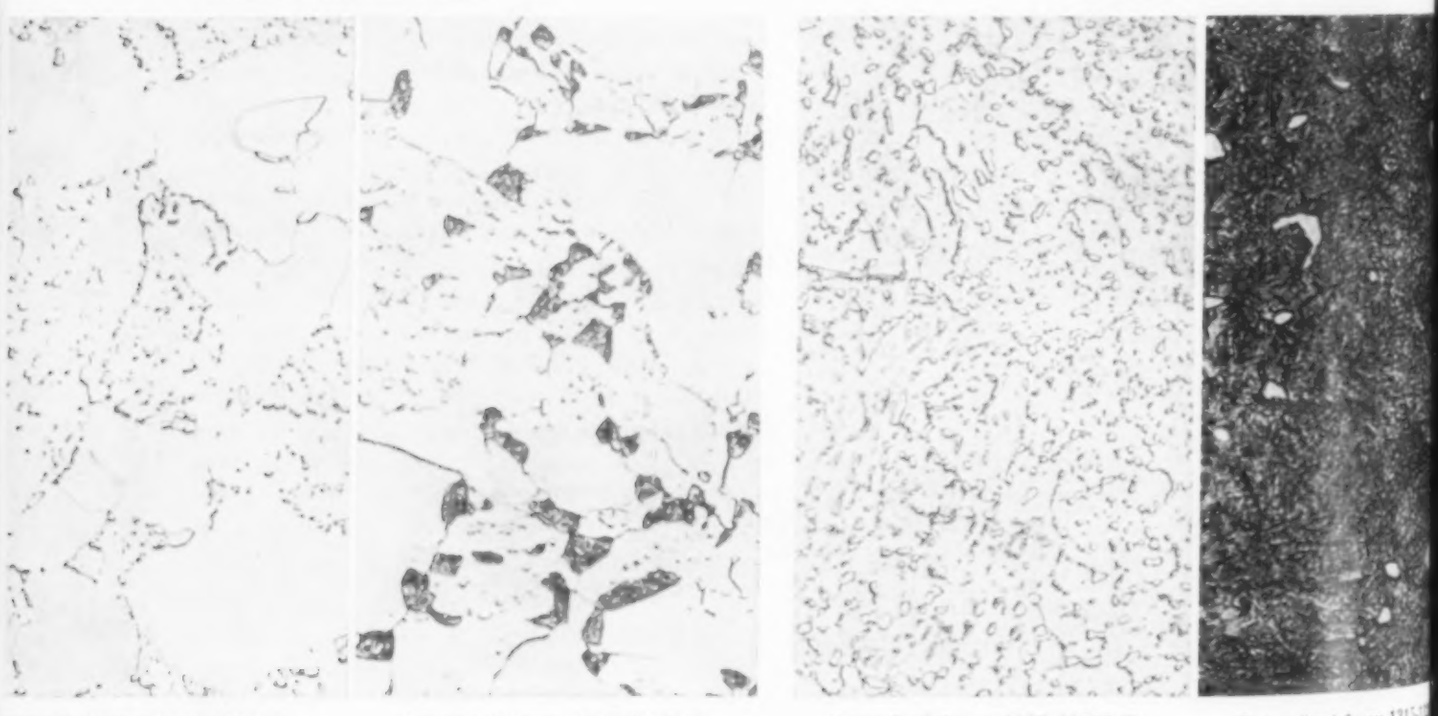
As a further check on the accuracy of these results and the consequent extrapolation to mark the Ae_1 values, small samples were cut from the bars from each heat, held 60 hr. at various temperatures ranging from 1280 to 1335° F. and water quenched. These specimens were then sectioned longitudinally and examined microscopically. Figures 3 to 6 show the structures obtained immediately below and above the Ae_1 temperatures predicted for each heat from Fig. 2. (Temperatures are given in ranges of 10° F., since the furnace was controlled within these limits.) All specimens were tempered at 700° F. to darken the martensite for easy observation.

It can be seen that an entirely satisfactory agreement was obtained between the Ae_1 temperatures predicted and the values observed from the quenching experiments. Heat 16207 (Steel A 4023) showed no traces of solution after 60 hr. at 1295-1305° F. and clear evidence of solution at 1305-1315° F. The high carbon heat 95521 (Steel A 4068) was also completely spheroidized at 1295-1305° F. but was substantially transformed after 60 hr. at 1315-1325° F.

Fig. 3 to 6 — Micrographs at 1000 X; Samples Water Quenched After 60 Hr. at Temperatures Noted; Drawn at 700° F. to Darken Martensite. Both steels had Ae_1 at 1305° F., as determined by dilatometer; both are spheroidized at temperatures just below 1305° F., and both have carbides dissolved at temperatures just above 1305° F.

Heat 16207; Steel A 4023

Heat 95521; Steel A 4068



uenched from 1295-1305° F. Quenched from 1295-1305° F. Quenched from 1295-1305° F. Quenched from 1315-

Sheet steel scrap for cupola charges

Information Supplied by "Metal Progress"

When certain precautions are observed, light steel sheet scrap (30 gauge and up) can be successfully used in cupola charges for making gray iron.

Black sheet is the best variety to use. The use of tinned, galvanized or stainless steel scrap sheet should be avoided.

When possible the scrap should be briquetted, or baled, before charging. Bundles should be smaller than those used in the open hearth, to prevent hanging in the cupola. The density of the bundles is important. Density can be controlled by varying the pressure exerted by the hydraulic press. In some cases a minimum density of 30% is specified.

When briquetting is not practicable for any reason it is possible to melt some light sheet in the charge by using a soft blast.

CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.
MOLYBDIC OXIDE—BRIQUETTED OR CANNED • FERROMOLYBDENUM • "CALCIUM MOLYBDATE"

Climax Mo-lyb-den-um Company
500 Fifth Avenue · New York City

MOLY

Personals

William P. Woodside, past president and founder member, vice-president, Climax Molybdenum Co., Detroit, has resigned as president of the American Twist Drill Co. and has become chairman of the board. He is succeeded as president by **William F. Murray.**

Lieut. **John A. Bailey**, assistant mechanical engineer, Frankford Arsenal, Philadelphia, is now on active duty in the Office of the Chief of Ordnance, War Department, Washington.

Louis A. Carapella has been made head of the Metallography Section in the Division of Physical Metallurgy at the Naval Research Laboratory, Washington, D. C.

IN the production of brass and aluminum fuses the reduction of "down time" to the least possible degree is all important!

Cutting operations on multi-spindle automatics, such as reaming, eccentric drilling, tapping and threading, respond to the application of Stuarts "Super-Kool" No. 151 Brass Cutting Oil, or Stuarts "Super-Kool" No. 1M Aluminum Cutting Oil frequently with a surprising improvement in tool life and finish.

For All Cutting Fluid Problems

D. A. STUART OIL CO.

Chicago, U.S.A. • LIMITED • Est. 1865

Warehouses in All Principal Metal Working Centers

R. S. Pratt, metallurgist, Bridgeport Brass Co., has transferred from Bridgeport, Conn. to the Indianapolis Ordnance Project of Bridgeport Brass.

George E. Dalbey, previously metallurgist with Abbot A. Hanks, Inc., San Francisco, is now in charge of metallurgical operations in the foundry at the Navy Yard, Mare Island, Calif.

Eugene G. Grace, president, Bethlehem Steel Co., has been presented the 1941 Bessemer Gold Medal by the British Iron & Steel Institute.

Charles R. Wade has left the employ of the Halcomb Steel Division to become the metallurgist of the Sunbeam Electric Mfg. Co. in Evansville, Ind.

M. B. Leidy is now Philadelphia district sales manager for Latrobe Electric Steel Co.

John J. Fitzgibbon, formerly foundry engineer for the Whitehead Metal Products Co., New York, is now metallurgist for R. Hoe & Co., Dunellen, N. J.

Promoted by Lindberg Engineering Co.: **Robert C. Onan**, from advertising manager to district sales manager for the Northern Illinois, Iowa, Wisconsin and Minnesota territory.

William G. Hassel, formerly manager of the Pittsburgh Crucible offices of Crucible Steel Co. of America, has been made manager of the Detroit office on the merging of the Pittsburgh with the Detroit and Cleveland offices. **Frank E. Phelps** remains manager of the Cleveland office.

N. H. Brodell has been appointed metallurgical sales engineer for Copperweld Steel Co., Glassport, Pa.

Harold P. Blum has been appointed by Metal & Thermit Corp. as its Cleveland territory representative, and will continue to represent Una Welding, Inc.

A Message of Confidence

THE war has brought many changes to the Bell System. The nation needed telephone facilities in new places. It needed more facilities in the usual places. It needed all facilities in a hurry.

Shortages of essential materials brought new problems and new achievements in research and in manufacturing. Telephone calls increased about ten million a day.

Yet all this has been done without great change in your telephone service. Millions of subscribers have felt no difference. The record as a whole has been good. That is the way it should be and the Bell System aims to keep it that way.

But when war needs delay your call, when you can't get just the service or equipment you need, let's put the blame right where it belongs — on the war.

BELL TELEPHONE SYSTEM

SERVICE TO THE NATION IN PEACE AND WAR

Personals

Walter R. Giese is now working for the Buick Aviation Engine Plant in Melrose Park, Ill. as a spectrographer.

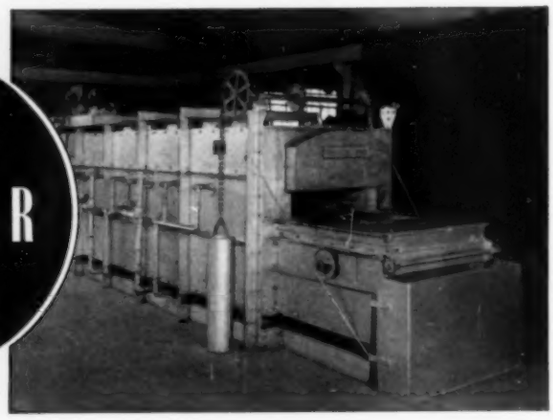
Walter J. Thomas, formerly with Consolidated Steel Corp., Ltd., is now welding engineer for the Western Pipe & Steel Co. of Los Angeles.

S. A. Oviatt, formerly engineer with Lamson & Sessions Co., Cleveland, is now a first lieutenant in the Army Air Corps, assigned to the Industrial Planning Section, Wright Field, Dayton, O.

Otto T. Pfefferkorn, formerly research metallurgist, Climax Molybdenum Co., Detroit, is now metallurgist in the aircraft division of Hudson Motor Car Co., Detroit.

200 TO 20,000 POUNDS OF METAL PER HOUR!

With CIRC-AIR Furnaces



Belt Type Hardening Furnace. Capacity 2,000 lbs. Per Hour.

Larger plant facilities and increased engineering and production personnel are putting more and more CIRC-AIR Furnaces to work in heat treating departments of war plants.

These furnaces are available in a wide range of sizes to meet varied production requirements from 200 to 20,000 pounds per hour, at temperatures ranging from 250 to 1250 degrees F.

CIRC-AIRS are used for drawing, bluing, soldering, steel and welded parts — Stress Relieving: Aluminum — for hardening, normalizing, drawing, billet heating for extrusion and forging: Brass — for annealing, coloring, sweating and soldering.

Write For Bulletins

CIRC-AIR HEAT TREATING EQUIPMENT

INDUSTRIAL HEATING EQUIPMENT CO.

3570 FREMONT PLACE • DETROIT, MICHIGAN

J. Hugh Braun, formerly inspector, Caterpillar Tractor Co., is now working at the Buick Aviation Engine Plant in Chicago, as a special assignment man.

John M. Dobovan, formerly assistant to chief metallurgist of Browning Machine Gun Division, AC Spark Plug, Flint, Mich., is now second lieutenant in the Ordnance Department, assigned to the Small Arms Division, Detroit Ordnance District.

Carl O. Sundberg, Jr. has resigned as assistant foreman with the American Steel & Wire Co., Joliet, Ill., to accept a position as an engineer with the War Department, St. Louis Ordnance District Office.

E. M. Thalheimer is now employed at the U. S. Rubber Plant in Des Moines, Iowa, as assistant chief metallurgist.

Oscar E. Swenson is research metallurgist in the Electrode Department at the new Metal & Thermit Corp. laboratory in Woodbridge, N. J.

Clifford Wiggins, previously chief metallurgist, Northwestern Steel & Wire Co., Sterling, Ill., member of the executive committee of the Rockford Chapter, is going to Warren, Ohio as special metallurgist for Federal Machine and Welder Co.

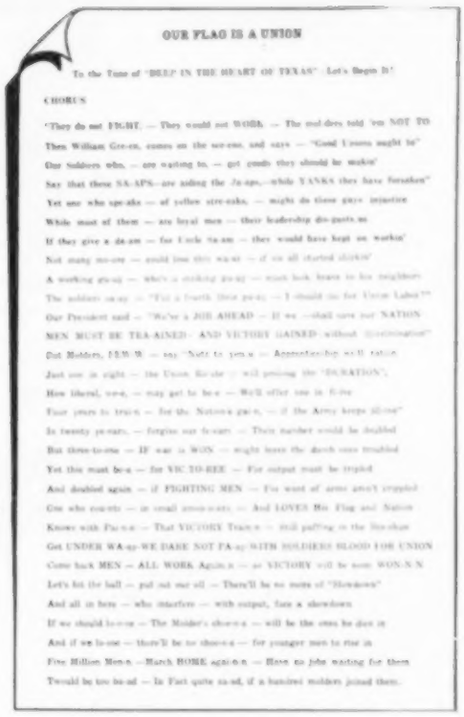
John J. Munro, formerly contact metallurgical representative, Carnegie-Illinois Steel Corp., is now with Goodyear Tire & Rubber Co., Jackson, Mich., as metallurgist.

Promoted: **A. H. Pepper**, past chairman, Montreal Chapter, to assistant manager of steel sales, Dominion Steel and Coal Corp., Ltd., Montreal.

George A. Uhlmeyer has been appointed supervising industrial engineer for Iowa-Illinois Gas and Electric Co., in charge of all industrial power and gas sales for member companies in ten cities.

FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

AN AMERICAN SONG
printed by the
Committee of
"SCABS"
at work at General Alloys Co.
The workers loyal to
Our flag who have
Kept working on
100% War Orders
Dedicated to the
"HEMOROIDS"
who struck without notice
and are still on strike
for reasons (if any) we can't find out
Members of International
Molders and Foundry Workers
Union - Local 106 - A. F. L.
With apologies to intimidated
workers who are with us in spirit
June 4th, 1942
WE KEEP 'EM FLYING
Our President said,
Defense Training Will Be Offered
to All Workers Without Discrimination



OUR FLAG IS A UNION

To the Tune of "DEEP IN THE HEART OF TEXAS" Let's Begin It!

CHORUS

"They do not FIGHT. — They would not WORK. — The real dirs told 'em NOT TO
Then William Green, comes on the scene, and says — "Good Unions might be"
Our Soldiers who, — are waiting to, — get goods they should be makin'
Say that these SA-APS—are aiding the Ja-aps,—while YANKS they have forsaken"
Yet one who speaks — of yellow streaks, — might do these guys injustice
While most of them — are loyal men — their leadership dis-gusts us
If they give a da-am — for Uncle Sa-am — they would have kept on workin'
Not many more — could lose this war — if we all started slackin'
A working group — who's a striking group — must look brave to his neighbors
The soldiers say — "I'm a Fourth Term guy, — I should go for Union Labor""
Our President said — "We've a JOB AHEAD — If we —shall save our NATION
MEN MUST BE TRA-AINED — AND VICTORY GAINED—without discrimination"
Our Molders, I.F.M.W. — say "NAY to you a — Accordin-ship will exist
Just one in eight — the Union Ra-ate — will prolong the "DURATION",
How liberal, we-e, — may get to be-e — We'll offer one in 5-five
Four years to train — for the Nation's gain, — if the Army keeps all over"
In twenty years, — forgive our fe-ears — Their market would be doubled
But three-to-one — IF war is WON — might leave the dutch once troubled
Yet this must be-e — for VICTO-REE — For output must be tripled
And doubled again — if FIGHTING MEN — Ev'ware of arms aren't crippled
One who resents — in small armaments, — And LOVES His Flag and Nation
Knows with Pa-ssion — That VICTORY Tra-in — will pull-ing in the Station
Get UNDER WA-ay WE DARE NOT FA-ay WITH SOLDIERS BLOOD FOR UNION
Come back MEN — ALL WORK Again-n — or VICTORY will be won WON-N-N
Let's hit the ball — put out our all — There'll be no more of "Slowdown"
And all in here — who interfere — with output, fare a slowdown
If we should lo-ose — The Molder's choo-ce — will be the ones he dies in
And if we lo-ose — there'll be no choo-ce — for younger men to rise in
Five Billion Men-n —March HOME again-n — Have no jobs waiting for them
Twould be too to-o-al — In Fact quite to-o-tal, if a hundred molders joined them.

OUTSIDE our office windows some gay patriotic lads are marching back and forth to the tune of "Keep 'em Flying, Uncle Sam" from a phonograph in our office. As they pass beneath two American Flags they jauntily lift their hats. They are General Alloys employees on strike. They have just been given a substantial increase retro-active to January First. They are members of the International Molders' and Foundry Workers' Union, A.F.L. They are under a regional wage agreement until January 1st, 1943. We have an Open Shop. They walked out without notice. In two days of crap-shooting before the State Board of Arbitration they haven't stated why they walked out. The only pretext was a coremaker without a card in an open shop. They have been twice requested by the Gov't. to return to work. Madame Perkins has just certified the "Dispute" to the War Labor Board. President Green of the A.F.L. stated "I did not authorize it, sanction it or approve it. It is contrary to the no strike policy of the American Federation of Labor. Union spokesmen say "Green's got no control over us". They called it a "VICTORY WALKOUT" and their picketing a "VICTORY DEMONSTRATION". They had been seriously retarding our production of War Orders, interfering with the training of men, producing abnormal scrap, and sub-normal production. Thirteen cases of sabotage have been certified to the Army and the F.B.I. A high ranking Air-Corps Officer said;—Unofficially;—"The company will probably get a reaming and be screwed-up in your production effort,—you had better just relax and enjoy it". We hope he is wrong. We have no intention of relaxing, and if any conditions are imposed on us which tend in any way to limit our production of War Materials we will go on record in a big way.

MEANWHILE, as these UNION ABOVE THE FLAG PATRIOTS are parading (few having any idea why they are out), LOYAL, FEARLESS, AMERICANS, STILL AT WORK ARE SETTING NEW PRODUCTION RECORDS, KNOCKING FROM ONE-THIRD TO ONE-HALF THE MOLDING TIME OFF PREVIOUS RECORDS AND GETTING OUT TWO-THIRDS THE NORMAL NUMBER OF HEATS. THEIR HEADS ARE HIGH AND THEIR HEARTS ARE CLEAN AS THEY DO THEIR PART FOR VICTORY,—GOD BLESS 'EM! More workers are returning to work each shift. What small production is lost will be quickly made up. When you read this we'll be going full blast, strike or no strike. A bit of "comedy relief" is the fact that the War Production Board's recent limitation on nickel has required revamping of our entire production schedule, design and pattern changes in many items, and this has coincided exactly with our "Victory Walkout". If our non-producing Patriots decide to return en-masse tomorrow we couldn't put them all to work until we could line up patterns for the new schedules. They seem to be drifting back to work on their individual consciences at about the right rate. As a labor-leader who jumped us for a loss once remarked—"You guys rape kinda hard". Unless politics holds us for labor, we still do! Seriously, THIS STRIKE TO PREVENT TRAINING OF MEN IN WAR TIME IS A DAMNED DISGRACE TO LABOR'S LEADERSHIP, AND TO THIS NATION. Congress, do your stuff, election is coming! Any argument we've heard in favor of War Production Strikes would gag a maggot. Called "Scabs" by strikers, our Loyal Workers coined a pet-name for War-Strikers,—"HEMORRHOIDS",—ponder on that one.

THE National nickel shortage did not catch us metallurgically unprepared. We will turn out the best "Ersatzalloys" possible under the name *"WAR-Q"* where a substitute for *Q-ALLOYS* is unavoidable, and under the name *WAR-X* where *X-ITE* is clearly indicated metallurgically, but disallowed in nickel rationing. It should be CLEARLY OBVIOUS, that the only POSSIBLE SAFEGUARD for maximum service from alloys diluted with excess iron, is THAT THE VERY BEST ENGINEERING, METALLURGY AND FOUNDRY PRACTICE BE EMPLOYED IN MAKING THEM.

HIGH nickel-chrome content has been a life-saver for lots of the run-of-the-steel-foundry alloys of the past, and a lot of engineered-down-to-a-good-job-for-the-foundry alloy casting designs. We are expecting about a 500% increase in failures and field service. Available engineering talent is the bottleneck. In this respect General Alloys Company is quite possibly best fitted to serve you if past performance is a criterion. 100% increase in our molding floor-space will be completed in June.

ED. NOTE: WIRE RECEIVED "STRIKE ENDED BY WAR LABOR BOARD—NOW WE'LL SEE IF GOV'T REPRIMANDS OR REWARDS THIS VICTORY DETERRENT—H. H. HARRIS."

Q-ALLOYS THE QUALITY NAMES IN ALLOY FOR HEAT CORROSION ABRASION X-ite

Personals

Bernard Collitt, metallurgist for Jenkins Bros., Ltd., Montreal, has been elected a director of the company.

C. R. Foreman, formerly with Saginaw Steering Gear Division, Saginaw, Mich., is now in the metallurgical department, Olds Motor Works, Lansing.

Richard G. Byrne of the advertising and promotion department of METAL PROGRESS, has enlisted for training as an ensign in the U. S. Navy.

Phillip W. Carbaugh, vice-chairman, Rockford Chapter, formerly assistant metallurgist, Mechanics Universal Joint Co., has left to become chief metallurgist of the Oliver Farm Equipment Co. at Charles City, Iowa.

IT'S MADE OUT OF
SPEED CASE STEEL
A LOW CARBON OPEN HEARTH PRODUCT

-because . . .

It increased production 25%

It increased tool life 33%

It saved $20.04 per ton of steel used

It swaged without fracture

Ductility Plus Machinability (230 SFPM)

In this "all-out" war effort Monarch Steel is co-operating 100%. We're helping to "keep 'em rolling" with Speed Case Steel.

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THE FITZSIMONS COMPANY
YOUNGSTOWN, OHIO

Licensor
MONARCH STEEL COMPANY
HAMMOND • INDIANAPOLIS • CHICAGO
PECKOVER'S LTD., Toronto, Canadian Distributor

MANUFACTURERS OF COLD FINISHED CARBON AND ALLOY STEEL BARS

Promoted: **W. R. Kuhn**, from assistant district manager to district manager of Allegheny Ludlum Steel Corp.'s Cleveland office.

Appointed on advisory committees to serve as liason groups between the Office of Price Administration and the industry represented: **A. C. Roeth**, Inland Steel Co., to the General Steel Products Advisory Committee; **R. M. Allen**, Allegheny Ludlum Steel Corp., **Norman L. Deuble**, Copperweld Steel Corp., **F. L. Gibbons**, Carnegie-Illinois Steel Corp., and **Martin H. Schmid**, Republic Steel Corp., to the committee on Armament Steels and Alloys; **John Graham**, American Steel & Wire Co., and **Ford Schusler**, Keystone Steel & Wire Co., to the Wire Products Advisory Committee.

Appointed on advisory committees to the Division of Industry Operations, War Production Board: **George Avril** of G. A. Avril Smelting Works, on the committee representing Brass and Bronze Ingot Makers Industry; **J. P. Jefferis** of Janney Cylinder Co. to the Brass and Bronze Foundries Industry; **Frederick G. Hughes** of New Departure Division, General Motors Corp., past president, to the Anti-Friction Bearing Industry.

J. L. Auer, general works manager, R. Hoe & Co., Inc., has been elected vice-president.

H. Lyon Day, formerly chief metallurgist at Ingersoll-Rand Co., Phillipsburg, N. J., is now consulting metallurgist for Auto Specialties Mfg. Co., St. Joseph, Mich. and for Lehigh Foundries, Easton, Pa.

Morton S. Umanoff, formerly senior engineering draftsman at Picatinny Arsenal, Dover, N. J., is now assistant mechanical engineer at the Signal Corps Laboratories, Fort Monmouth, Red Bank, N. J.

MOLYBDENUM · TUNGSTEN · BORON

MCA

Boron has joined the Alloys!

Tungsten, Molybdenum, Boron—Boron, Molybdenum, Tungsten—interest concentrates now on one alloying element, now on another, as of crucial importance for the war. Very marked attention is at present given to Boron, because of new knowledge that has recently been brought to light.

Minute additions of this relatively abundant element, to steels and irons, yield properties otherwise obtained only by use of scarcer imported materials. One specific advantage in many cases is deep penetration of hardening effects, accompanied by an increase of yield and ultimate strength.

Researches on Boron have been conducted for some time by the Molybdenum Corporation of America and more recently verified under a fellowship at a leading university. A patent for the effective incorporation of Boron in irons and steels has been secured and its results will be made available to any American manufacturer. Inquiries are welcomed.

AMERICAN Production, American Distribution, American Control—Completely Integrated.
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MOLYBDENUM
CORPORATION OF AMERICA, Grant Building, Pittsburgh, Pa.

Ears on Brass Cups*

STRIP of any of the metals used for deep drawing operations occasionally yields cups that are defective because of a rim that varies in height around the cup in a wave-like manner. When the protuberances formed (usually four in number on brass and other copper alloys) are symmetrically disposed with respect to the rolling direction of the strip, they are invariably attributable to the metal. The effect is known as "earing" and the protuberances are called "ears". Other terms frequently heard are "tips", "scallops" and "corners". It is recognized that the effect is most commonly a result of a directional crystal structure produced by rolling and annealing operations in the manufacture of the metal strip.

This matter has been under investigation by American Brass Co. for several years, and while it is obviously impossible to present all the details, the statements made in this paper have been amply substantiated either by laboratory tests or actual drawing of metal in the brass mill.

The tools used in the drawing process, or the type and completeness of lubrication, have nothing to do with the problem of ears, although they do, of course, greatly affect the "drawing quality" of the strip and the general appearance of the cup. A single tip may be drawn up on the rim of a cup because of misalignment of the tools, or because the gage of metal varies from side to side of the strip. The two-ear form that sometimes appears is also traceable to gage variations. However, the four-ear and six-ear symmetrical forms are caused by factors inherent in the structure of the metal itself.

It is now common knowledge that deformation of metals takes place by slip in certain definite directions on certain definite planes in the crystalline metal grains. In normal polycrystalline brass the individual crystalline grains are oriented at random, so that approximately equal numbers of planes of easy slip are available for deformation in any direction. In cupping such material, the blank will draw-in uniformly all around its circumference and no ears will appear. However, if for any reason the crystal orientations of the individual grains of a strip become aligned, the strip as a

*From "Effect of Some Mill Variables on the Earing of Brass in Deep Drawing" by Earl W. Palmer and Cyril Stanley Smith, Technical Publication No. 1444, American Institute of Mining and Metallurgical Engineers.

To Treat 'Em Rough
Heat-Treat 'Em Right
R-S Furnaces of the latest and improved designs are heat-treating metal parts of ships, tanks, guns, aircraft and other implements of war with unfailing uniformity. The hum of production is increasing to a full-throated roar.
Benefit by our long experience and extensive facilities for prompt action. Write, 'phone or wire for detailed information.
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R-S Furnaces of Distinction

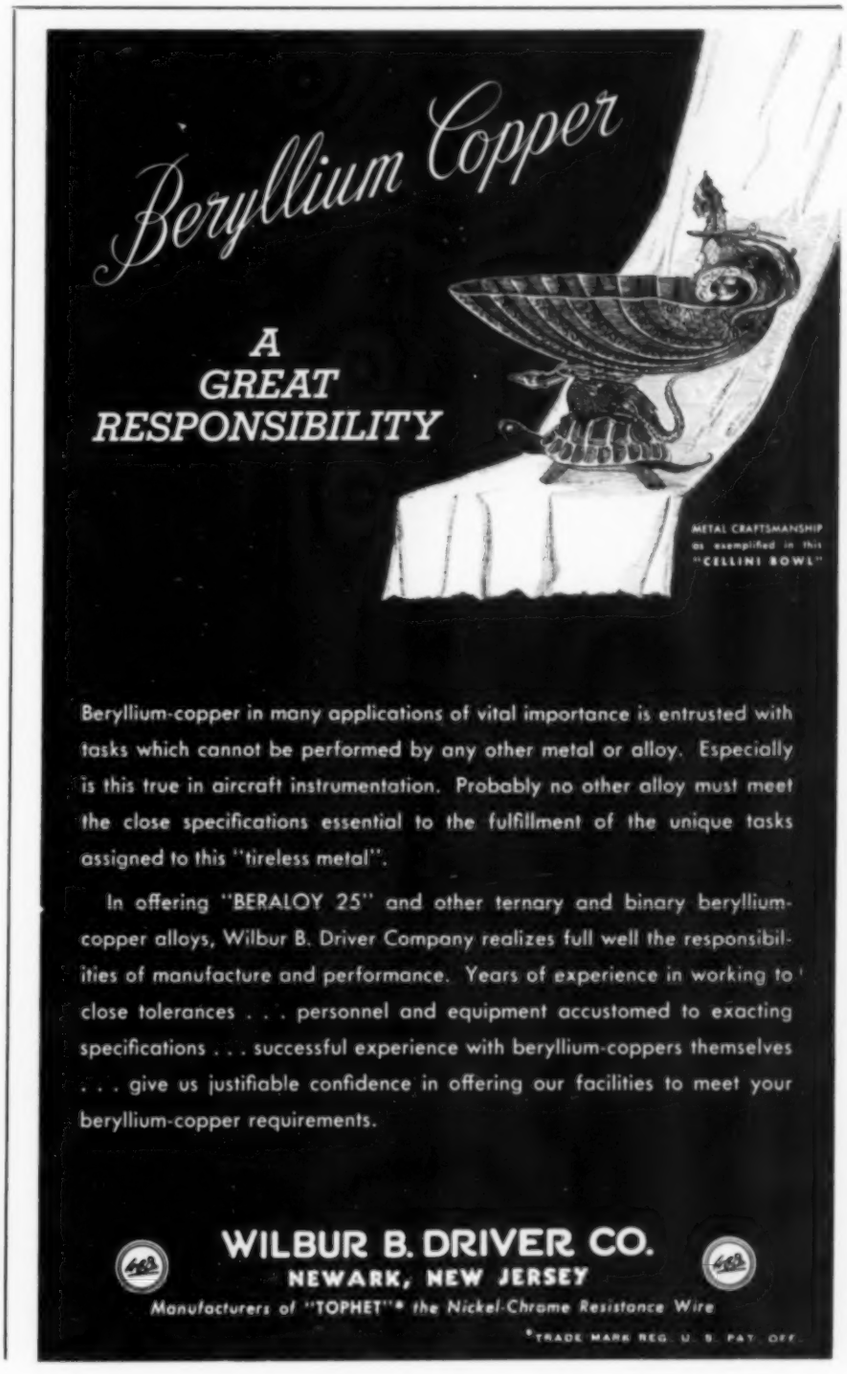
whole will behave more or less like a single crystal, and its deformation characteristics will thereupon vary with direction. In a cupping operation such material will produce ears of a height that depends upon the perfection of the grain alignment.

Under uni-directional deformation, as in normal rolling practice, the individual grains of an annealed material are not only progressively fragmented, but the crystalline fragments are actually *rotated* by the process, so that all tend to align themselves in definite relation to the direction of rolling. (Such crystallographic action has been proved for numerous single phase metals, both by microscopic examination and by X-ray crystal analysis.) For a given grain size the degree of alignment, or directionality, depends almost entirely upon the amount of deformation, unless the crystals in the annealed material are already ranged directionally, as a result of previous mechanical and heat treatment. Whatever the extent of structural alignment in a rolled strip, it is in some degree preserved after annealing. The precise orientation of the new crystals in the annealed material usually differs from that of the fragments in the rolled material, although the two are closely related.

Directionality may be detected, prior to cup formation, by X-ray diffraction photographs and in extreme cases by alignment of twin bands in the microcrystals. It is also evident in variations in precision measurements of the modulus of elasticity in tensile tests cut at various directions to rolling. However, all these methods are difficult to use and require expert appraisal.

Unimportant Factors—Before discussing the factors that do have some bearing on the development of earing tendency, it seems desirable to dispose of some that are popularly, but erroneously, supposed to be of importance. These may be listed as type or speed of rolling mill, number of passes, reduction per pass, or lubrication. It makes no difference whether the strip is rolled always in the same direction, or turned end for end between passes. Cross rolling does affect directionality but since this operation is not commercially feasible with strip metal it may be dismissed here.

Other factors of no influence are surface finish, composition (that is, common impurities, although in alpha brasses the earing tendency increases with the zinc content), deoxidation practice, and size and orientation of grains in the ingot. Gage of strip and size of cup influence the actual *height* of ears (when the metal forms ears) only as would be predicted from the geometry of the shapes.


Beryllium Copper
A GREAT RESPONSIBILITY
METAL CRAFTSMANSHIP as exemplified in this "CELLINI BOWL"
Beryllium-copper in many applications of vital importance is entrusted with tasks which cannot be performed by any other metal or alloy. Especially is this true in aircraft instrumentation. Probably no other alloy must meet the close specifications essential to the fulfillment of the unique tasks assigned to this "tireless metal".
In offering "BERALOY 25" and other ternary and binary beryllium-copper alloys, Wilbur B. Driver Company realizes full well the responsibilities of manufacture and performance. Years of experience in working to close tolerances . . . personnel and equipment accustomed to exacting specifications . . . successful experience with beryllium-coppers themselves . . . give us justifiable confidence in offering our facilities to meet your beryllium-copper requirements.
WILBUR B. DRIVER CO.
NEWARK, NEW JERSEY
Manufacturers of "TOPHET"* the Nickel-Chrome Resistance Wire
*TRADE MARK REG. U. S. PAT. OFF.

Ears on Brass

(Starts on page 832)

While earing is usually traceable to the alignment of grains in annealed strip, other causes are occasionally found. Material finished with a light cold reduction (sometimes done to improve gage of surface) may show slight ears when cupped. Partially recrystallized material behaves similarly. Finally, strip metal in which appreciable coring persists, or which contains streaks of beta or other constituent, may develop ears as a result of its mechanical fiber.

Mill Practice — However, the most important factors affecting directionality are the amounts of reduction given to the metal between anneals (especially at the final and ready-to-finish stages) and the temperatures of the various anneals — two factors which are interrelated in a complex fashion.

Study of definite rolling and annealing schedules shows an exceedingly complex relationship with earing tendency. However, the following summary can be made of known facts about the effect of annealing temperatures:

1. As long as the material is fully recrystallized, the higher the final annealing temperature, the greater, invariably, is the ear height.

2. The lower the ready-to-finish annealing temperature, the greater, invariably, is the degree of final directionality. The magnitude of this effect naturally varies widely with the amounts of ready-to-finish and final reductions involved.

3. The lower the temperature of the running-down anneals, the greater will be the directionality after any final anneal. This is true for schedules involving reductions up to 8 B. & S. numbers between anneals, but is not always true where very high reductions are involved.

4. Rolling fine-grained annealed material results in the continued development of a still higher directionality. Ears far higher than those obtainable with the heaviest straight rolling may be developed in brass rolled with only 4 to 6 B. & S. numbers reduction by a succession of intermediate anneals at a low temperature (650 to 850° F.).

Schedules of heavy reductions developed to minimize the earing tendency are limited by the practical consideration that in stands with the ordinary two-high rolls about 20 in. in diameter, it is uneconomical to roll brass more than about 6 B. & S. numbers without annealing. Under these conditions, when earing occurred it was inevitably a result of low processing anneals, and if the ready-to-finish annealing temperature was raised the ears disappeared. *(Cont. on page 836)*

DURALOY

High Alloy Casting SERVICE

. . . meeting today's problem of heat, corrosion and abrasion by skillful use of available alloying elements. Industrial equipment need not suffer from heat, corrosion or abrasion in its greatly stepped-up production program. There is still an imposing battery of alloying elements available and by proper selection and use of these, and by proper heat treatment, castings can be given desirable characteristics. Duraloy Metallurgists, long skilled in this important work, will be glad to help work out your casting problem and then turn out these castings for you.

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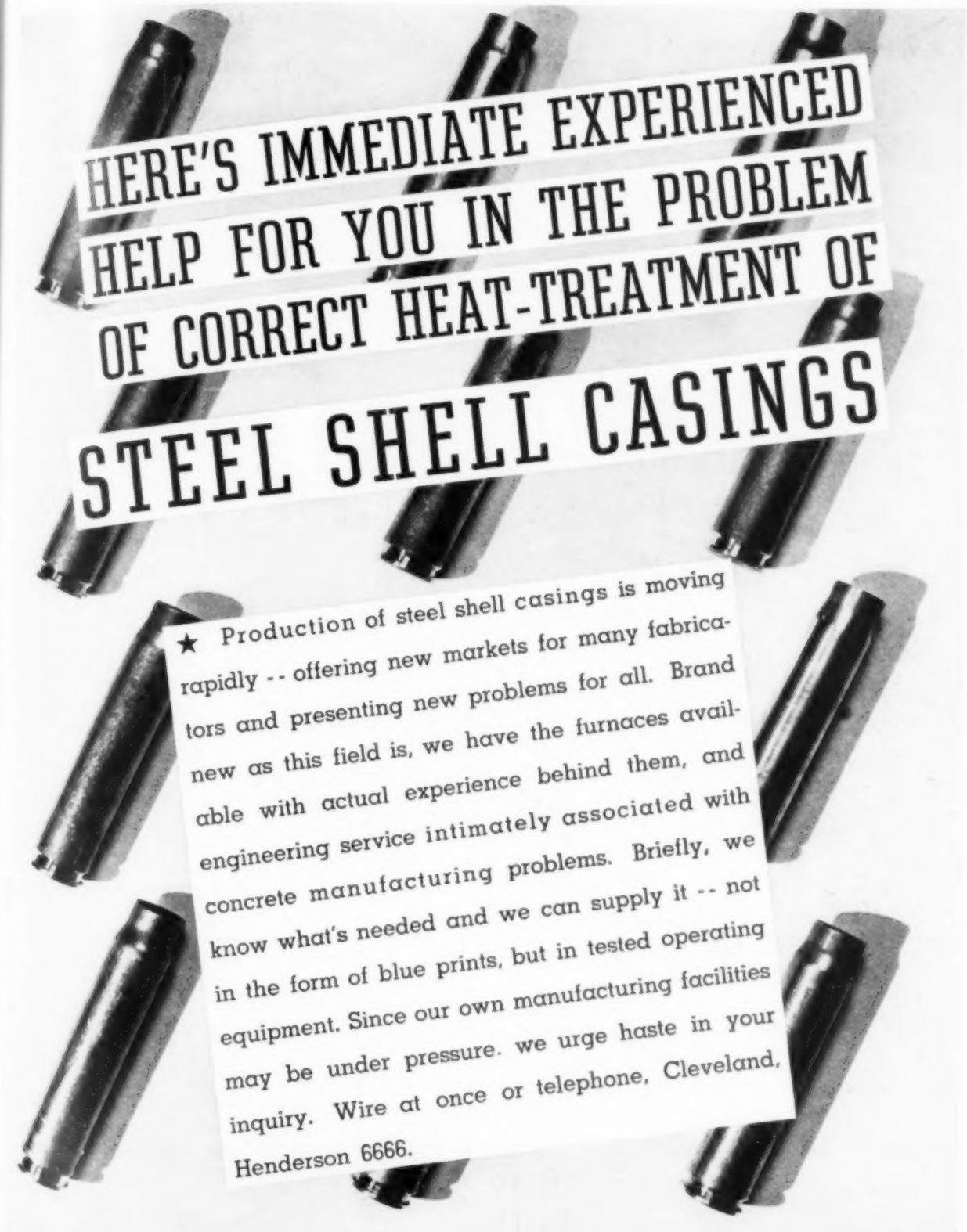
Metal Goods Corp.: St. Louis—Houston—Dallas—Tulsa—New Orleans

6-DU-3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HELP FOR YOU IN THE PROBLEM
OF CORRECT HEAT-TREATMENT OF
STEEL SHELL CASINGS
★ Production of steel shell casings is moving rapidly -- offering new markets for many fabricators and presenting new problems for all. Brand new as this field is, we have the furnaces available with actual experience behind them, and engineering service intimately associated with concrete manufacturing problems. Briefly, we know what's needed and we can supply it -- not in the form of blue prints, but in tested operating equipment. Since our own manufacturing facilities may be under pressure. we urge haste in your inquiry. Wire at once or telephone, Cleveland, Henderson 6666.
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5005 EUCLID AVENUE CLEVELAND OHIO
BUILDERS OF PRECISION HEAT-TREATING FURNACES AND FLASH BAKERS

Ears on Brass

(Starts on page 832)

Recent introduction of four-high rolls permits very heavy reductions between anneals and makes "earing tendency" a factor of far greater importance, and sometimes prevents the use of production schedules otherwise highly desirable and economical. Two methods, each of limited applicability, of utilizing the reduction capacity of the new mills while still avoiding ear formation have so far been found by us:

1. With common high brass and other copper-zinc alloys, the directionality resulting from an amount of reduction up to at least 22 numbers can be thoroughly broken up by a high temperature anneal (1200° F. or above) followed by a light reduction (4 B. & S. numbers). Material so processed will be satisfactorily free from ears after final annealing temperatures up to 1050° F., and even after a 1200° anneal is acceptable for most applications. The limitations of this method are associated with the difficulty of producing material of satisfactory gage and surface after the high temperature ready-to-finish anneal.

2. It has been found, with 65-35 and other brasses that are to be rolled at least 26 B. & S. numbers from the overhauling point to finish, that this reduction can be made with but a single properly placed intermediate anneal. A schedule of 1400° F. anneal, 16 numers reduction, 1400° anneal, 18 numbers reduction produces satisfactory strip 0.009 in. thick with the usual range of final annealing temperature. Similarly satisfactory strip 0.020 in. thick can be made with the following schedule: 1400° F. anneal, 12 numbers, 1400° F. anneal, 15 numbers.

Variation from the optimum intermediate gage in these schedules is apt to be dangerous, and the entire schedule must be planned at the beginning and adhered to.

This method of rolling is obviously not suitable for odd lots, but is promising for the production of large quantities of material if equipment is available to give the heavy reductions required and to handle thick, hard metal.

Prediction of the earing tendency that will result from a given production schedule is not always possible. Each factor influences the others to a greater or less extent, and no simple rules of behavior can have universal application. In general, the various factors will operate in the manner described, but only a cupping test on a trial lot of strip can evaluate the summation of their effects.

FOR GREATER WAR PRODUCTION

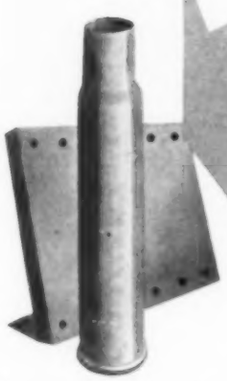
In the production of practically all essential machinery and materiel for our armed forces, heat treatment plays a vital part . . . For the furnaces and the handling of the work in the furnaces,—dependable long-heat-hour heat-resistant alloys are needed to insure maximum results.

It will pay you to replace parts where strains are heaviest and anticipate requirements. MICHIANA with 24 years of specialized experience in the production of heat-resistant and corrosion-resistant alloys, is ready to make recommendations that may save your time, and speed up essential production. MICHIANA PRODUCTS CORP., Michigan City, Indiana.

MP CORP.

ENGINEERED AND *Ready*

ARMOR PLATE AND STEEL SHELL CASING FURNACES



Complete plant layouts for heat treatment of armor plate and steel shell casing have been engineered and designed by Continental — and approved by several manufacturers.

Jobs involving both types of heat treatment have been ordered, and Continental is beginning to roll on actual production of these furnaces.

If you are interested in the production of either armor plate or steel shell casing, Continental can duplicate or adapt these completed designs to give you prompt deliveries.

Materials and equipment are now being ordered for this type of production. Phone, wire or write us now for early delivery dates and other details on these specialized heat treating setups.

Also Consult Continental On —

TANK PARTS	ROLLING MILLS
AIRPLANE PARTS	GUNS
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SHELLS	DESTROYER TUBES
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FURNACES *for* **VICTORY**

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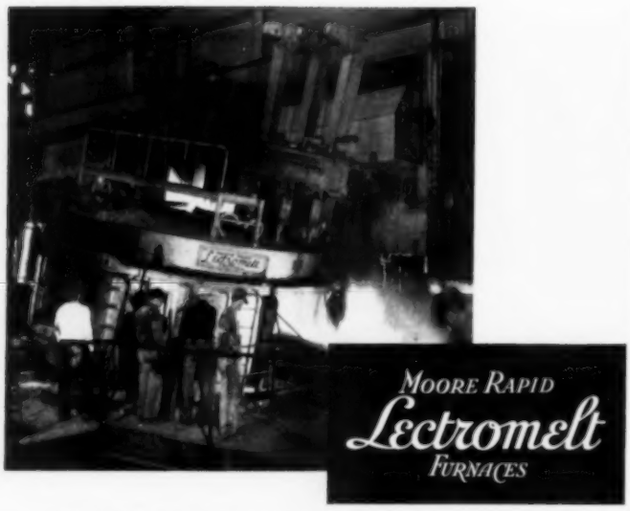


The fine performance and reliability of Lectromelt arc furnaces is contributing in a vital way to the increased tempo of armament programs. Built in standard sizes from 100 tons to 250 pounds capacity, Lectromelt top charge furnaces are showing appreciable savings in power, refractories, electrodes and man-hours.

PITTSBURGH LECTROMELT FURNACE CORPORATION
FOOT 32nd STREET PITTSBURGH, PA.

for **SPEEDY** SPECIMEN CUTTING . . .

TRY THE

Jarrett Submerged Specimen Cutter

Low speed submerged cutting with a rubber bonded wheel features this new Specimen Cutter.

Intermediate grinding or machining of specimens is eliminated by this newly developed cutter because the surface it produces is ready for the polishing operation after mounting in the specimen press.

The cutting wheel, vise, and specimen are wholly submerged in water, eliminating over-heating and burning as well as washing away foreign particles and preventing burring.

With this equipment, hardened steel, coarse grained products, ores as well as all the usual soft materials can be cut without injury, producing an even section with parallel planes. Specimens 8" long and 1½" diameter may be cut with ease on this machine. Both ends of the specimen are held firmly in a double jaw vise. Write for details on this and other features of the Jarrett 3-step Polishing Method.

TRACY C. JARRETT
METALLURGICAL POLISHING EQUIPMENT
P. O. BOX 3155 CATONSVILLE, MD.

Rolls-Royce Aero-Engine

THE BRITISH publication *The Engineer*, in issues dated Feb. 27 and March 6, 1942, printed photographs, drawings and description of the Rolls-Royce "Merlin XX" liquid cooled supercharged engine, the power plant of many of Britain's best fighters and bombers. It is a V-12; cylinders are 5.4-in. diameter by 6-in. stroke. It develops 1260 brake horsepower at 12,250-ft. cruising altitude (low supercharger gear) and 1175 hp. at 21,000 ft. elevation with high supercharger gear, and weighs 1450 lb. (about 1¼ lb. per hp.). It is cooled with ethylene glycol (prestone) solution, safe against freezing to arctic temperatures; the cooling system is under pressure sufficient to boost the boiling point of the coolant to 250° F.

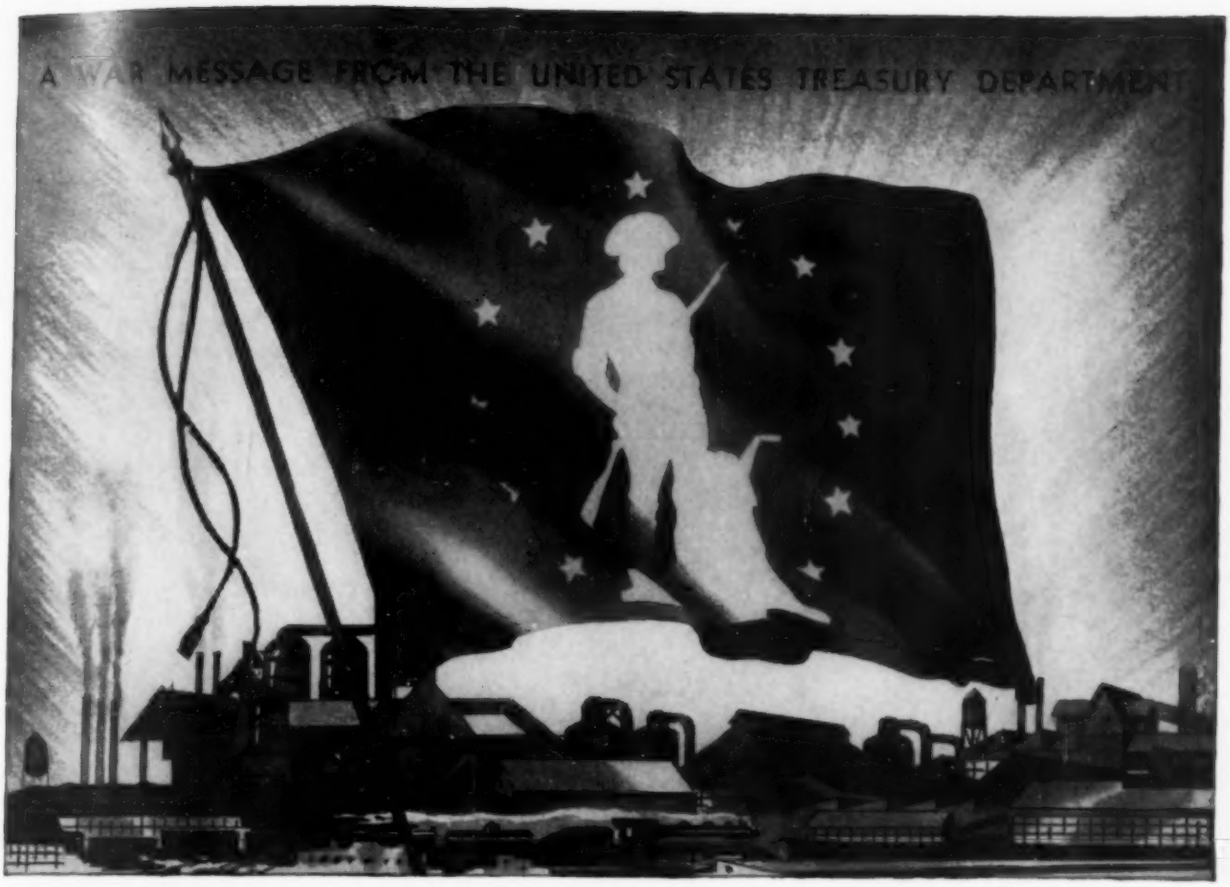
The above mentioned articles say that advantages claimed for the liquid-cooled in-line aero-engine from the point of view of small frontal area, minimum drag, and its capacity for high specific power output, have been more than substantiated during the present conflict. All the high performance fighter aircraft at present in the service in the Royal Air Force are powered by liquid-cooled in-line engines; similarly the fastest fighters in the air forces of all the nations involved in the war are equipped with this type of engine. Americans have more intensively studied and perfected the air-cooled radial engine, and even as early as the Battle of France the Curtis fighters "Hawk 75's" with radial engines distinguished themselves for their maneuverability, and are probably responsible for the recent appearance of the new German "FW 190" fighter, powered with a 1600-hp., 14-cylinder, air-cooled radial motor.

The Merlin XX has been "souped up" so its maximum power has been advanced 14.5% with a weight increase of only 8.5%. The gain is largely from improvements in supercharger and magneto design, and this has been achieved despite the necessity of muffling the exhaust so no flame will appear at night.

Each cylinder and coolant jacket is a single aluminum alloy casting; the cylinder liner is a thin steel tube. Other aluminum castings, some highly complicated, form the crank case and gear cases, both front and rear.

Hollow camshafts are carried on aluminum pedestal forgings, mounted on the cylinders.

(Continued on page 844)



Next to the Stars and Stripes . . .

AS PROUD A FLAG AS INDUSTRY CAN FLY

Signifying 90 Percent or More Employee Participation in the Pay-Roll Savings Plan

IT doesn't go into the smoke of battle, but wherever you see this flag you know that it spells Victory for our boys on the fighting fronts. To everyone, it means that the firm which flies it has attained 90 percent or more employee participation in the Pay-Roll Savings Plan . . . that their employees are turning a part of their earnings into tanks and planes and guns *regularly,* every pay day, through the systematic purchase of U. S. War Bonds.

You don't need to be engaged in war production activity to fly this flag. Any patriotic firm can qualify and make a vital contribution to Victory by making the Pay-Roll Savings Plan available to its employees, and by securing 90 percent or more employee participation. Then notify your State Defense Savings Staff Administrator that you have reached the goal. He will tell you how you may obtain your flag.

If your firm has already installed the Pay-Roll Savings Plan, now is the time to increase your efforts: (1) To secure wider participation and reach the 90-percent goal; (2) to encourage employees to increase their allotments until 10 percent or more of your gross pay roll is subscribed for Bonds. "Token" allotments will not win this war any more than "token" resistance will keep our enemies from our shores, our homes. If your firm has yet to install the Plan, remember, TIME IS SHORT.

Write or wire for full facts and literature on installing your Pay-Roll Savings Plan now. Address Treasury Department, Section D, 709 12th St., NW., Washington, D. C.

Make Every Pay Day "Bond Day"

U. S. WAR Bonds ★ Stamps

Rolls-Royce

(Continued from p. 838)

Exhaust valve stems are hollow and they are filled with sodium in order to assist the transfer of heat from the valve head to the cooling area. They are made in special high quality heat resisting steel, and the valve heads and seating faces are covered with "brightray", a nickel-chromium alloy resistant both to heat attack and to the lead content in the gas. Tips of both inlet and exhaust valve stems are covered with stellite to prevent wear by contact with the tappet. The valve seats, which are screwed into the aluminum cylinder head, are made from special heat resisting steel; the valve guides, which are of cast iron for the inlet valves and phosphor bronze for the exhaust valves, have tapered shanks and are pressed into the block.

A balanced hollow crankshaft is employed, which is made from a one-piece steel forging, nitrided on wearing surfaces. It has a flange at its forward end which transmits the drive through a splined coupling to the airscrew reduction gear. It is carried in seven bearings, each lined with special lead bronze, which are housed in the top half of the crank case.

All the connecting rods are H-section steel forgings, machined all over, and are of the forked marine type. Steel bearing shells lined with lead bronze are used for the big ends and for the plain rod bearings, which work against the outer surface of the forked rod blocks. Pistons are aluminum forgings, furnished with three pressure rings and two drilled scraper rings; pins are of hardened steel and are of the floating type.

The supercharger rotor is produced from an aluminum alloy forging, which is designed to withstand the large stresses set up by high speeds and elevated temperatures; its maximum operational speed is in the neighborhood of 29,000 r.p.m.

A good general idea of the complexity of the modern aero-engine is conveyed by the fact that there are approximately 11,000 separate parts in the "Merlin XX" engine. Included in these are 4500 different varieties of parts. The total engine weight of 1450 lb. is divisible as follows: Steel, 47%; aluminum, 43.6%; brass and bronze, 2.5%; other materials, 6.9%. This latter item includes rubber, plastics, magnetos and ignition wires. Only 12 different classes of steel are used throughout the engine, including special purpose steels, while one grade of cast aluminum alloy is employed, and two grades of wrought aluminum.

FOR TOTAL VICTORY

Stop ALL Leaks!

Serving the United Nations with dependable gaskets for every application.

STEELBESTOS • TWIN-TYPE STEELBESTOS • KORKOID • SPRINGOID
DELOID • D-G INSULATING MATERIALS • SYNTHETIC COMPOSITIONS

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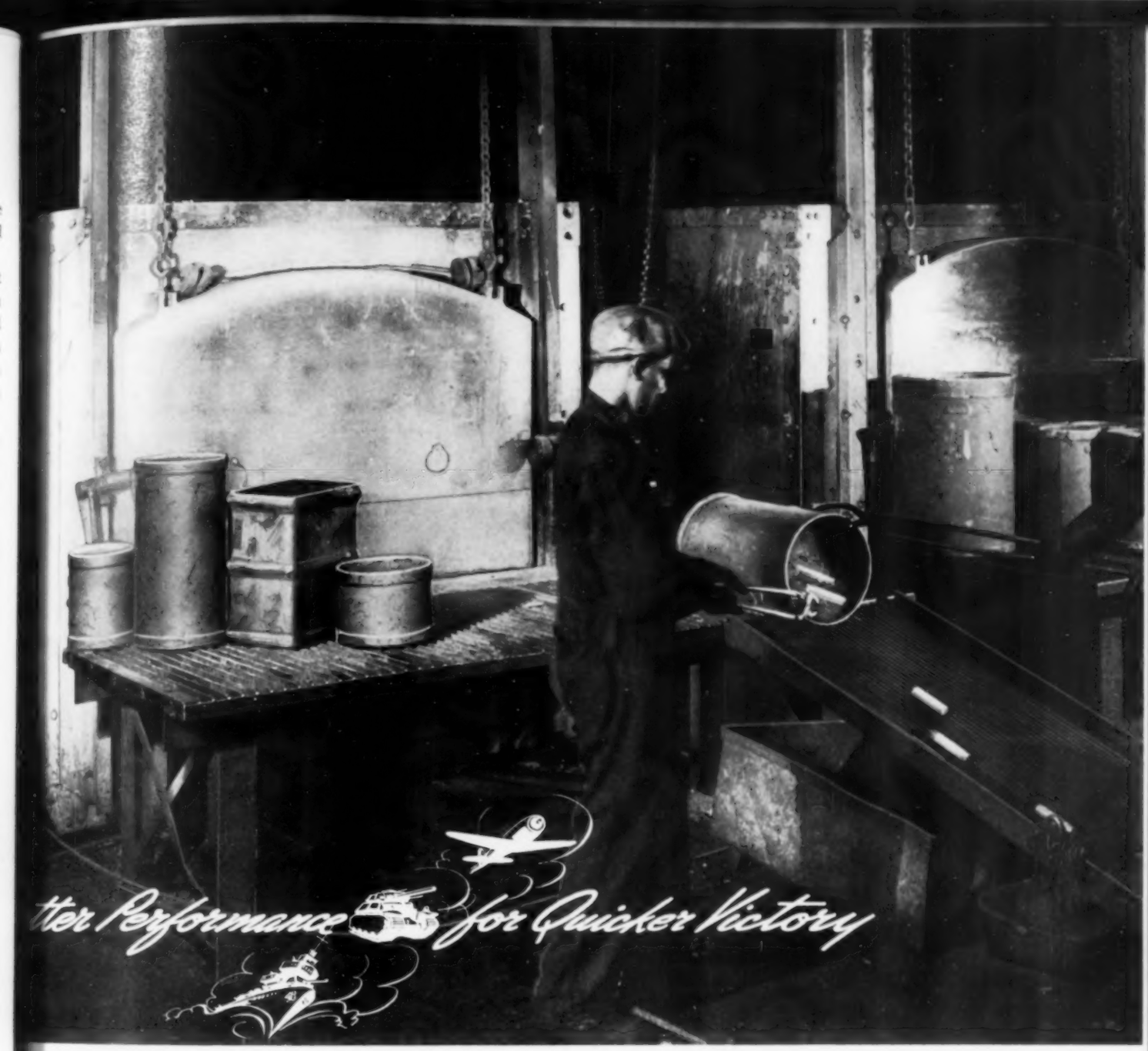


HEAT TREATING EQUIPMENT

. . that weighs less and lasts longer!

A group of Pressed Steel Company Carburizing Boxes of various types used by the Perfection Tool & Metal Heat Treating Co. This mid-western heat treater has been using Pressed Steel Company equipment for many years.

THE PRESSED STEEL COMPANY

of WILKES-BARRE, PENNSYLVANI

BRANCH OFFICES: 337 Curtis Bldg., Detroit; 1914 Vermont Ave., Toledo; 205 Engineers Bldg., Chicago; 254 W. 31st St., New Yo

PRESSED STEEL COMPANY PRODUCTS: Carburizing and Annealing Boxes, Thermocouple Protection Tubes, Seamless Steel Cylinder Caps, Seamless Steel Neck Rings, Welded Alloy Tubing for High Temperature and Corrosive Application

Strategic and Critical Materials

As of June 1, 1942

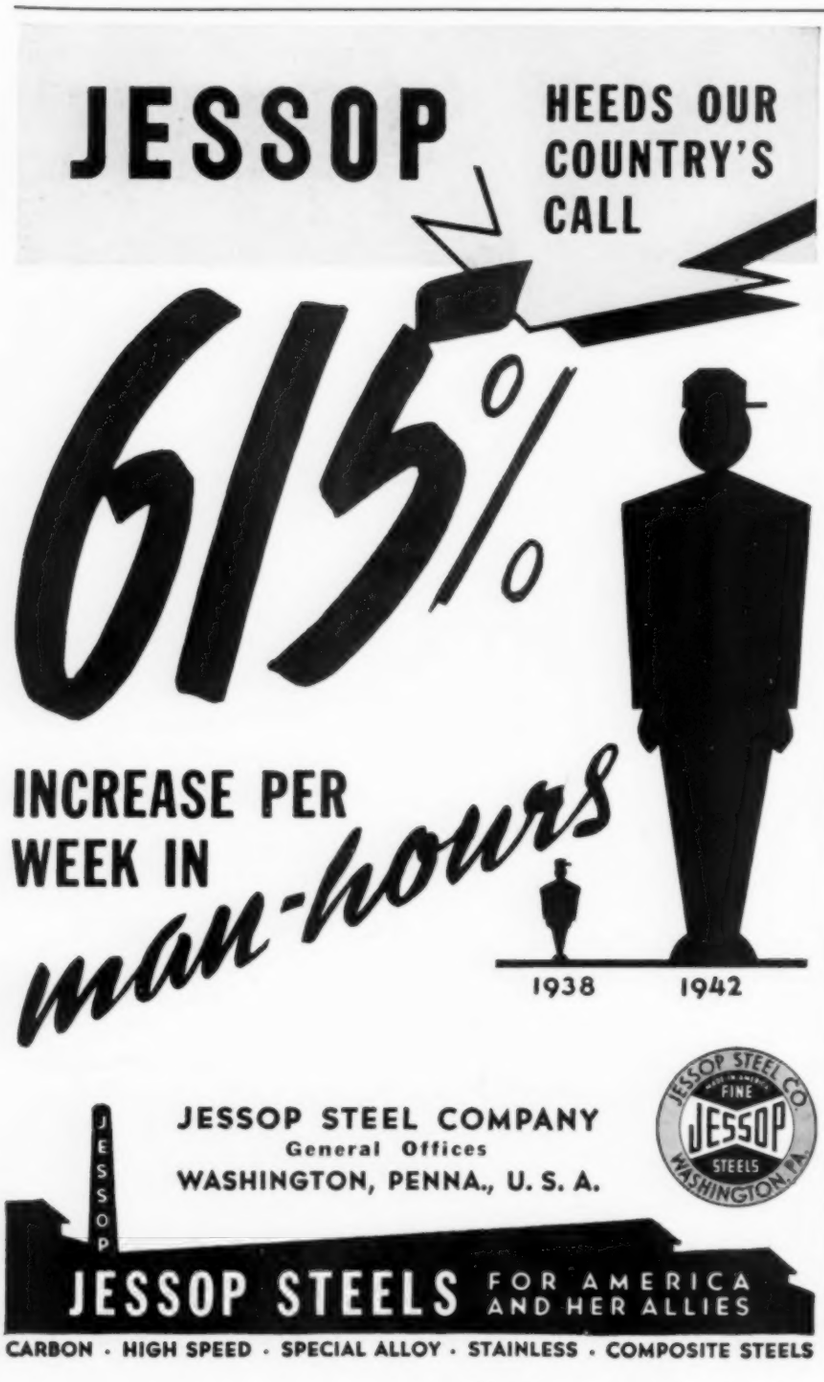
LISTS OF METALS and of non-metallic products used by the metallurgical industries are issued by War Production Board from time to time, showing the relative scarcity of certain materials. The current list, when compared with the one issued on March 12, shows few of these materials to be in an easier position; most of them are scarcer. This general trend is a prime reason for the impending change from the inadequate priorities system to a control based on allocation of supply to meet expected quarterly consumption of the vital armament industries.

In these lists Group I consists of materials whose supply is inadequate — in many cases even for the armed services. Metals newly added to this group are columbium, electrolytic manganese and tantalum. When comparing the list with that presented in METAL PROGRESS in April (page 552), it is seen that rhodium, high grade zinc, ammonia and palm oil have been elevated from Group II to Group I, whereas aluminum scrap and lead have dropped to Group II (those materials essential to the war industries, but which are not so scarce).

Group III, listing materials available in quantity, is practically void of metals, but does contain 16 non-metallic domestic minerals used in the manufacture of molding materials, refractory brick and furnace linings, such as bentonite, diatomaceous earth, spodumene, andalusite, kyanite, and sillimanite. Group III, "plentiful materials", contains gold (try and get any!), indium, osmium and silver. Items now promoted to Group II are bismuth, palladium, ruthenium, silicon and its alloys, uranium, pig iron and iron castings. New substances appearing in Group II are ferrosilicon, lithium and magnesite.

HARVEY A. ANDERSON, chief of the Conservation and Substitution Branch of the Bureau of Industrial Conservation, notes that the change of position from a lower group to a higher, due to depletion of supply, is frequently because of deficiencies in substituted materials.

In the third group most of the items are used with little change from the natural condition. Even where there are almost unlimited supplies, as of lumber, oil, and cotton, certain varieties or grades have become scarce. Further, in the case of large tonnage items, the problems of labor, manufacturing, and transportation have become increasingly important.


JESSOP
HEEDS OUR COUNTRY'S CALL
615%
INCREASE PER WEEK IN man-hours
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JESSOP STEELS FOR AMERICA AND HER ALLIES
CARBON · HIGH SPEED · SPECIAL ALLOY · STAINLESS · COMPOSITE STEELS

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STEEL CASTINGS
WEIGHT for War Needs!

war has emphasized the value of a highly mechanized with large numbers of airplanes, fast-firing guns, and tanks. All of this equipment today requires *castings!*

of the big advantages in using steel castings is to *lighter, stronger parts* . . . thus saving WEIGHT metal. In building trucks, for example, every pound makes room for another pound of man-power, -load, or gun-power. That's why so many truck facturers are turning to steel castings for parts that ighter in weight, without the slightest sacrifice of gth and long life.

castings today are remarkably versatile . . . bringing performance and lower costs to a wide range of me products. Particularly important are the big s in assembly and finishing costs that result from igh accuracy and uniformity of castings produced odern steel foundries.

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Indianapolis, Indiana
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Engine
Food Processing & Packing Plant
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Hoist & Derrick
Iron & Steel Industries
Metallurgical Machinery

Mining Machinery & Equipment
Oil or Gas Field & Refinery
Ordnance
Overhead Crane & Charging Machine
Paper Mill
Printing Press
Pump
Railroad
Refractory, Brickyard & Ceremic
Refrigeration Machinery

Road & Building Construction
Rubber Mill
Ship & Marine
Shoe Machinery
Smelting Plant
Spray Painting Equipment
Steam Turbine
Street, Elevated, & Subway Cars
Textile Machinery
Valves, Fittings & Piping
Well Drilling Equipment

Contribution of Statistics

to the Science of Engineering*

By Walter A. Shewhart

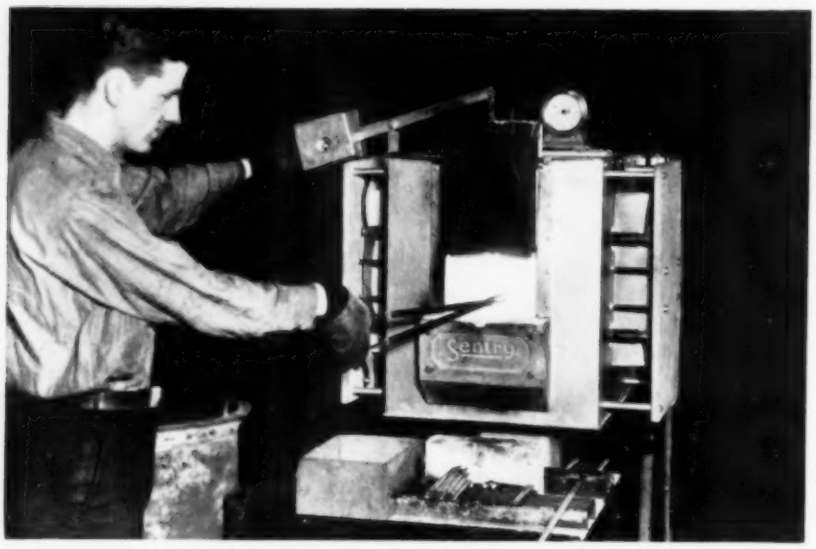
ONE OF THE MOST REVOLUTIONARY principles ever introduced into manufacturing was that of interchangeability. It dates back at least to ELI WHITNEY in 1798. The principle of interchangeability prompted the engineer to consider the advantages of repetitive operations in production processes. The contribution of statistics to engineering may be thought of as a means of maximizing the advantages to be attained by interchangeability, for the statistical control can modify and coordinate the processes of mass production by minimizing tolerances and maximizing the assurance of meeting specifications.

In all engineering processes there is an element of probability. The engineer devises an operation that, if carried out, will produce the thing wanted. Since he does not claim perfect knowledge of facts and physical laws, the best he can hope to do is to know the *probability* that the manufacturing operation will hit the target, so to speak. But before using the probability theory the engineer should understand the conditions under which it will lead to valid predictions. The applied mathematical statistician has provided us with such rules, but they are valid only when the samples are taken at random.

Let us assume that we have N physically similar chips on each of which is written a number and that these N chips are placed in a bowl. A blindfolded experimentalist thoroughly mixes the chips in the bowl, draws a number, and has his assistant record the number. The chip is then returned to the bowl and the blindfolded experimentalist, after another thorough mixing of the chips, again draws one and has the number recorded. This random operation of drawing a number can theoretically be repeated again and again under the same essential conditions so as to give an infinite sequence. (Many experimenters have tried with their eyes open, as it were, to juggle a set of numbers into what they would instinctively call "random order", only to find that the sequences thus obtained did not possess the characteristics of sequences *(Cont. on p. 856)*

*Abstracted from a paper before the University of Pennsylvania Bicentennial Conference, September, 1940.

Buy Your Atmosphere *by the* PACKAGE



Size 2 Model Y Sentry Furnace in operation.

Prevent hardening failures in high speed steel tools! Get clean tools free from decarburization! Eliminate grinding after hardening! Harden any high speed steel alloy without failure.

You can do all this economically and easily with Sentry Furnaces and Sentry Diamond Blocks.

Write for Bulletin 1020-3A

Sentry "Always on Duty"

The Sentry Company

FOXBORO, MASS., U. S. A.

FOR CHEAP INSURANCE - - -
Use Wheelco LIMITROLS

The cheapest insurance you can buy for your plant is *Preventive Insurance.* Wheelco Limitrols provide *Preventive Insurance* by protecting you against the losses excessive temperatures can cause in your processes.

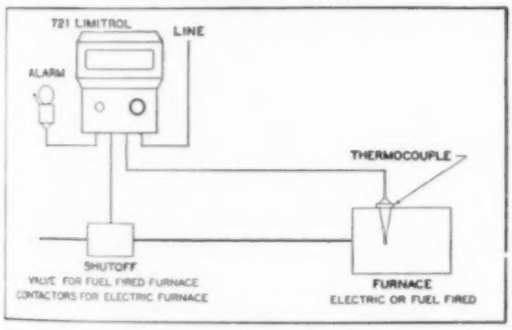
The Limitrol combines a high resistance pyrometer with an electrically operated automatic shut-off device to give you (1) continuous, accurate, temperature readings, and (2) automatic shut-off of heat input when the temperature measured reaches a point selected and set on the pyrometer scale.

The Limitrol may be used as a safety device to prevent temperature from rising above a danger point, or to insure shut-down of equipment, at any desired temperature, to obtain the exact material specifications required.

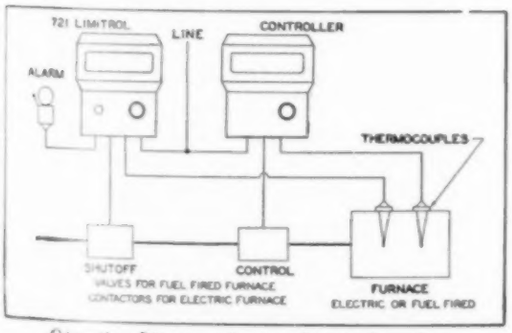
Investigate the applications for Limitrols in your plant.

Wheelco Limitrol.

Diagrams below show typical methods of installing Limitrols.



Operating Diagram showing use of Limitrol only.



Operating Diagram showing Limitrol used in conjunction with a temperature controller.

LIMITROL FEATURES

Can be used in conjunction with controllers of any type, or it can be used alone.

Protects equipment from being overheated due to failure of control or switching apparatus.

Equipment cannot be turned on again until temperature has dropped to safe limit.

Any point on the scale can be selected as a shut-off point.

Thermocouple Break—Will shut off equipment if thermocouple is broken.

"Radio Principle"—Limitrols employ the famous Wheelco "Radio Principle" Control.

Limitrol Scales—6" long.

Scale Ranges—0 to 3600° F. or equivalent °C.

Write today for your copy of Limitrol Bulletin No. D202-3.

Wheelco Instruments Co.
835 HARRISON STREET • • • CHICAGO, ILLINOIS

Statistics

(Continued from page 854)

obtained by drawing from a bowl with their eyes shut!)

In most engineering work there is some distinguishable physical operation by means of which the results of the operation can be randomized. Application of the operation of randomization is important in the comparison of new designs, new materials or alloys, study of contact phenomena under different conditions, corrosion of materials under different atmospheric conditions, field trials of equipment, to make sure that observed differences are not due to some assignable cause in the original operation.

Most sequences obtained by a random operation possess certain characteristics that almost no sequence of results from repetitive engineering operations possesses until after all assignable causes have been eliminated. And yet the maximum assurance of meeting specified tolerance limits is obtained only when the repetitive operation obeys a law of chance.

Two courses of action are open: One is to use available statistical technique as a *curative* measure in the sense of screening the product obtained by repeating a given production operation when this operation does not obey a known law of chance. The other is to develop a statistical technique to be used as a *preventive* measure in the sense of providing a means of detecting and eliminating assignable causes of variability that need not be left to chance.

Basic Hypothesis for Statistical Control — It is feasible and often desirable to establish a scientific method of modifying an existing operation until it obeys the law of chance. We shall consider the hypothesis of control in three parts.

Hypothesis I: The maximum attainable degree of validity of prediction that an operation will give a value lying within any previously specified tolerance limits, is that based upon the prior knowledge of the law of chance underlying the operation.

Hypothesis II: The maximum degree of attainable control of the cause system underlying any repetitive operation in the physical world, is that wherein the system of causes produces effects in accord with a law of probability. Such a state of control has been termed a *statistical state* of control.

Hypothesis III: It is assumed that some criteria may be found and methods developed for their application to the numbers obtained in a sequence of repetitions of any operation such that whenever a failure to meet the criteria is observed. *(See p. 858)*

★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★

"AMERICA, HURRY!"

Pearl Harbor! Wake Island! Singapore! BATAAN! MANDALAY! CORREGIDOR!! Lost--because we sent "too little, too late".

TANKS, PLANES, SHIPS, GUNS, SHELLS AND BOMBS are the sinews of war. If not produced in countless numbers —TODAY AND TOMORROW—THE WAR MAY SOON BE LOST! AMERICA, HURRY!!

***SPEED* PRODUCTION! *SPEED* DELIVERIES! *SPEED* SHIPMENTS!**

★ HOW? Let Pangborn show you. Show you the vital services the ROTOBLAST Barrels, Tables and Cabinets—the Air Blast Rooms, Cabinets and Special Equipment—the Dust Collectors and Control systems are performing for others daily.

★ One ROTOBLAST Barrel just installed replaces twenty-three tumbling mills—and in eight hours cleans more work than the combined mills turned out in twenty-four—and does the job BETTER—at a LOWER COST.

★ A ROTOBLAST Table cuts cleaning time on fragile work 50 percent—ELIMINATING THE WASTE THAT FORMERLY CAME FROM REJECTS DUE TO BREAKAGE AND WARPAGE.

★ A manufacturer of bombs finds it easy to clean the inside and outside of these weapons since he asked Pangborn to help him—AND NOW HIS PRODUCTION IS THREE TIMES WHAT IT USED TO BE.

★ Pangborn technical, sales and research facilities are available to help you SPEED UP PRODUCTION—the benefits of thirty-eight years experience as the World's largest manufacturer of Blast Cleaning and Dust Control equipment are yours for the asking. Use Pangborn help to get MORE OF EVERYTHING MADE OF METAL TO THE YANKS.

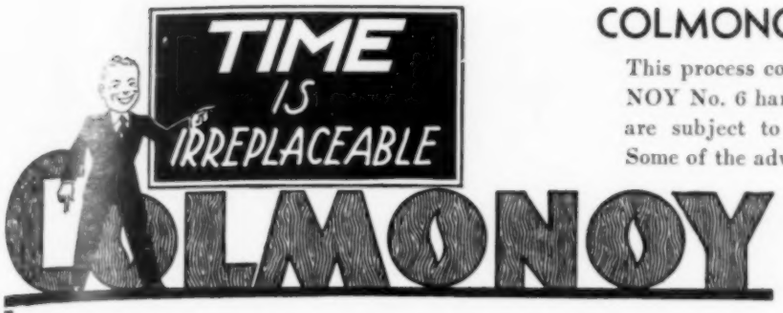
THE WAR WON'T WAIT!

AMERICA, *HURRY!!*

PANGBORN

WORLD'S LARGEST MANUFACTURER OF DUST COLLECTING AND BLAST CLEANING EQUIPMENT

PANGBORN CORPORATION . . . HAGERSTOWN, MARYLAND



COLMONOY FURNACE WELDING

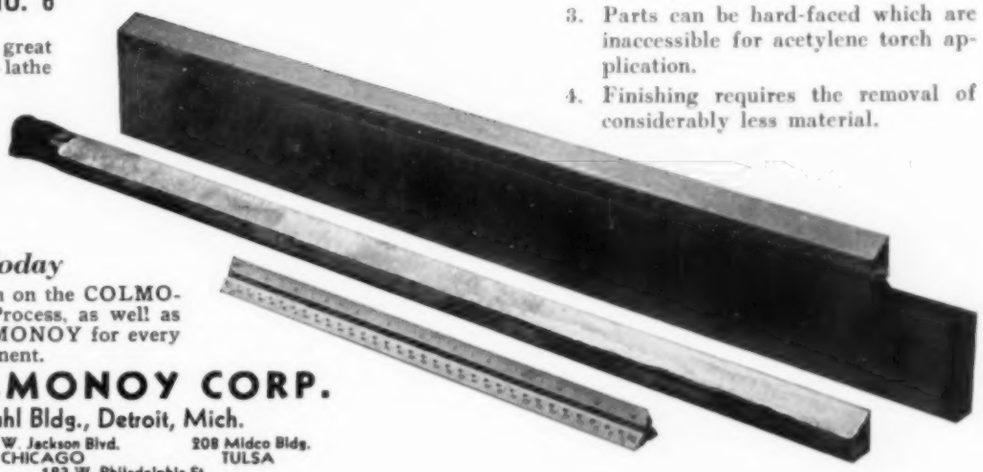
This process consists of applying a casting of COLMONOY No. 6 hard-surfacing alloy to steel base parts that are subject to corrosion, abrasion, wear and galling. Some of the advantages of this process are:

SAVES VALUABLE TIME

1. It is adaptable to high production parts.
2. There is complete freedom from porosity and cracks.
3. Parts can be hard-faced which are inaccessible for acetylene torch application.
4. Finishing requires the removal of considerably less material.

USE COLMONOY NO. 6

on parts subject to great wear and abrasion — lathe points, dogs, chip breakers, drill flutes, wire straightening shoes, thrust bearings, screw machine fingers, forming and drawing edges, etc.



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Ask for full information on the COLMONOY Furnace Weld Process, as well as all the grades of COLMONOY for every hard surfacing requirement.

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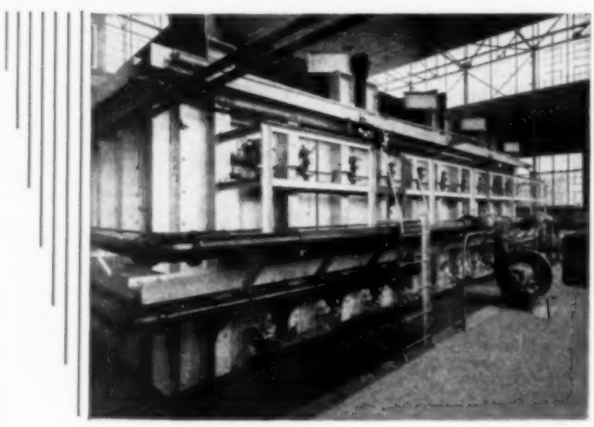

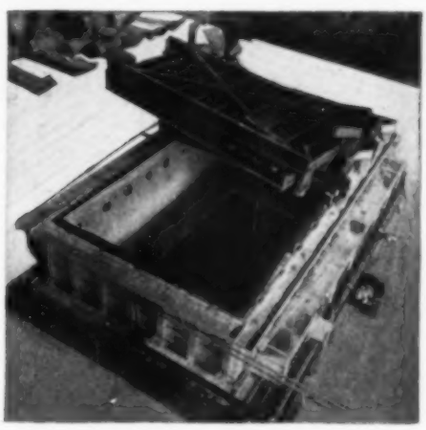

Pit Furnace for Annealing Large Gun Mount Castings

ORDNANCE and INDUSTRIAL FURNACES

ALL SIZES	ALL TYPES	ALL PURPOSES
From the largest Billet Forging and Plate Heating Furnaces to Bolt Headers and small Portable Forges	In and Out, Car, Conveyor Pusher, Roll Down, Rotary Horizontal and Vertical Pit Circular and Rectangular Pot	Forging, Soaking, Hardening Quench & Draw, Auto-Frettage Annealing, Stress Relieving Hardening, Tempering, Nosing

DIRECT FIRED — RECIRCULATING — RECUPERATIVE — REGENERATIVE
AUTOMATIC OR MANUAL CONTROLS
Gas, Oil and Combination Gas and Oil Burners

TATE-JONES & COMPANY, INC.

LEETSDALE, PA.

FURNACE ENGINEERS AND MANUFACTURERS SINCE 1898

Statistics

(Continued from page 856)

an assignable cause of variability in the results given by the operation may be discovered and removed from the operation. It is further assumed that, by the removal of a comparatively small number of causes, a state of statistical control is approached where the results of repetitions of the operation behave in accord with a law of chance.

Basic Experimental Data for Attaining Control — Inspection samples of lots taken in the order of their production have long been used in applying the operation of statistical control. However, it is essential that the record of the order of repetitions be preserved even though the experimentalist judges the conditions to be essentially the same. He may suggest certain ways of ordering the results of *n* repetitions of an operation, solely upon his knowledge of the conditions under which the observations were taken, in order to reveal trends or erratic effects likely to exist. Or he may arrange the results in groups and test for assignable causes.

Basically, what is done is to note two kinds of runs in any sequence: Runs up and down, and runs of numbers above and below the average of the sequence. If the assignable causes simply produce erratic shifts in the expected values, it is not likely that the distribution of lengths of runs-up and of runs-down will be much disturbed, but such shifts will tend to give extra long runs of numbers above and below average. However, if the assignable causes produce trends with slopes large in comparison with the fluctuations produced by the superimposed causes acting at random, the distribution of lengths of runs-up and runs-down will be disturbed. Likewise, the distribution of runs of numbers above and below the average of the sequence may be somewhat modified.

Thus, a study of the results will give a clue to the type of the assignable cause and the point at which it enters. In rolled material, for instance, lack of symmetry in the rolls will produce different trends from those caused by slippage at the cleavage planes of the crystals.

This information about assignable causes is lost when we group the data together in the form of a frequency distribution, as is so often done by the engineer. One can almost always find and remove assignable causes, when they are indicated, and thereby approach a state of statistical control beyond which it is not possible to go except by some fundamental change in the operation itself.

ELASTUF "44"
Doorway for Thousands of Miles of Wire . . . .

Because of its Remarkable STRENGTH

Solder dies must possess peculiar qualities—they must have great strength to withstand the tremendous pressures used, they must hold size accurately, and withstand the heat employed in extrusion. Previous alloy and tool steels used were far from satisfactory due to their failure in one or another respect. But a new steel, ELASTUF "44," has ended this headache.

Through the die pictured, thousands of miles of wire have passed without measurable change in size. What makes the difference? ELASTUF "44" is a machinable heat treated steel. Its compression strength is well over 200,000 lbs. It has remarkably uniform hardness throughout the cross section. These qualities are proving valuable allies to industry today when uninterrupted production is so important.

Read more about this steel in this booklet
"ELASTUF STEELS IN ACTION"

This booklet is a collection of cases showing how ELASTUF Steels are meeting tough problems of application and service. If you design machine parts or select Machinery Steels, you'll find this booklet helpful. It also contains the famous Machinery Steel Selector. A copy is available, without obligation, to all Department Heads in Purchasing, Engineering and Plant Management. Address Machinery Steel Division at the nearest address below.

ELASTUF STEELS

BEALS-McCARTHY & ROGERS • **BUFFALO-ROCHESTER**
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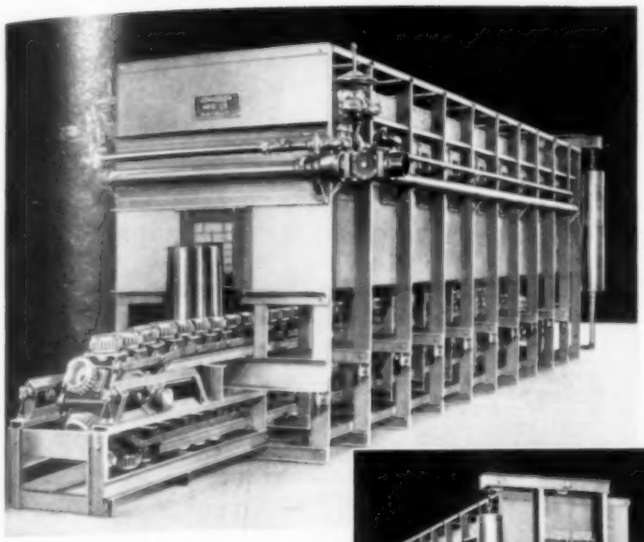

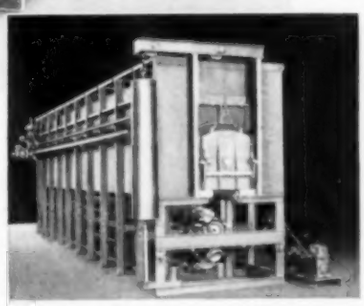

The New Johnston Shell Nosing Furnace

This Johnston Furnace for Shell Nosing---

1. Rotates the shells to insure even heating.
2. Heats the shells in the nosing position to eliminate regripping between the furnace and nosing press.

- **FURNACES**
- **BURNERS**
- **BLOWERS**
- **CONTROLLERS**

Manufactured Under Accurate Control in Our Own Efficient Factory

JOHNSTON MANUFACTURING CO.

MINNEAPOLIS, MINNESOTA

PURE
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metals

Tungsten Powder	97-98%
Pure Manganese	97-99%
Ferro-Chromium	60%
Pure Chromium	98-99%
Ferro-Tungsten	75-80%
Ferro-Titanium	25 & 40%
Ferro-Vanadium	35-40%
(1% Silicon)	

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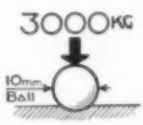
THE **KING PORTABLE BRINELL**

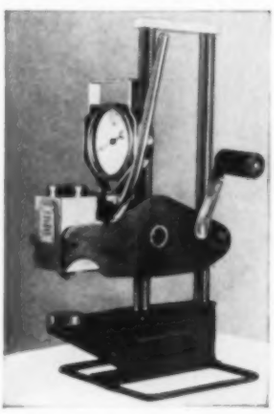
A HARDNESS TESTER FOR PORTABLE AND STATIONARY USE



Puts an actual load of 3000kg. on a 10 mm. ball.

Throat, 4" deep.
Gap, 10" high.
Weight, 26 lbs.

Can be used in any position—even upside down.



Test head removable for testing larger pieces beyond the capacity of the standard base.

ANDREW KING

NARBERTH, PENNA.

Notes About Contributors

in This Issue

Mabel MacFerran Rockwell's disarming smile conceals an unusual accomplishment for a woman in the field of electrical engineering. The fact that she should successfully acquire a B.S. in electrical engineering from Massachusetts Institute of Technology, followed by a M.S. in the same field from Stanford, is somewhat less unusual than her subsequent ten years' experience in test work and power system design for Southern California Edison Co. and for the Metropolitan Water District of Southern California, working on the Colorado River Aqueduct. She joined Lockheed Aircraft Corp. in 1938 as plant electrical engineer, and since 1939 has had the title of production research engineer. Interest in the wedge-draw test currently being described in a series of three articles in METAL PROGRESS, resulted from efforts of the production research group to place sheet metal forming on a basis of sound technical control.

Given Brewer, co-author with Mrs. ROCKWELL, is also a graduate of M.I.T. with a B.S. in general engineering in 1938. He joined the Lockheed organization as a mechanical engineer in the manufacturing engineering department that August, but left a year later to assist in the construction of radio station WNBH in New Bedford, Mass. In April 1940 he returned to join the newly formed production research division of the engineering department at Lockheed. He is now senior research engineer in this division.

C. E. Peck was born in Pittsburgh, where he has evidently decided to stay. After attending Pittsburgh public schools, he picked a local college, Carnegie Tech, and received his Bachelor of Science degree in mechanical engineering in 1928. After a year working with Prof. W. TRINKS, head of the mechanical engineering department at Carnegie Tech, he joined the Westinghouse Co. in East Pittsburgh as a student in the Design School. In 1935 he was made heating section engineer; prior to that he worked for several years in the development section of the generator engineering department.

While still a youngster **Joseph H. Jones** left school in 1917 to join the Army. With the end of the war he returned to civilian life and joined the Studebaker Corp. at South Bend in 1920. He stayed with Studebaker until 1935 and during his last seven years there learned a great deal about the development, production, testing, and servicing of transmission and rear axle units as well as all automotive gears. With this metallurgical background Mr. JONES joined Republic Steel Corp., Alloy Division, Massillon, in 1935 as a field contact metallurgist. His work has included various special assignments, the latest one being the development, testing, and directing the application of NE steels for his company.

C. E. PECK

MABEL M. ROCKWELL

GIVEN BREWER

JOSEPH H. JONES

New Book On Hardness

It has been some time since any book has handled any subject so comprehensively as Prof. Williams deals with hardness in his new book, Hardness And Hardness Measurements, just published by the American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio.

As Professor of Physics at Amherst College, Prof. Williams has devoted twenty-five years of study and experience to every phase of hardness and hardness testing—and the results are packed into this big 558-page reference book.

339 illustrations depict almost every branch of this field and make the book so informative that it should be on your desk as a constant guide to procedure in any type of hardness problem.

Here are just a few of the subjects dealt with . . . atomic structure in relation to hardness . . . underlying conditions in hardness measurements . . . wear resistance in relation to hardness . . . early, recent and modern scratch hardness methods . . . early penetration hardness methods . . . Brinell and Rockwell hardness testing methods . . . pendulum method of measuring hardness . . . hardness tests on various non-metallic materials—and on and on.

Containing 22 chapters and a large appendix and bibliography, this new book is a "must" for your metallurgical reference library.

HARDNESS AND HARDNESS MEASUREMENTS

558 Pages . . . 339 Illustrations . . . 6" x 9"

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Official U. S. Navy Photos

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Mills at Ambridge, Pa. and Chicago, Ill. · Warehouse Stocks in Principal Cities

Manufacturers of Carbon and Alloy Steels . . . Turned and Polished Shafting

Turned and Ground Shafting . . . Wide Flats up to 12" x 2"

New Products Available

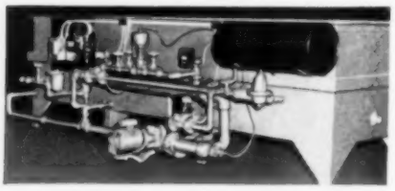
Readers may obtain complete details on these products by writing to METAL PROGRESS. We will gladly pass requests on to the manufacturer. Simply mention the paragraph numbers of the items in which you are interested.

New Radiation Pyrometer

Pyrovac is name of new radiation pyrometer designed for recording, indicating, or automatically controlling temperatures in furnaces and kilns above 900° F. The temperature-sensitive unit is mounted on the outside of the furnace out of the hot zone where it picks up heat rays emitted from the object under measurement, thus registering its surface temperature. (No. 56)

Wash Tank

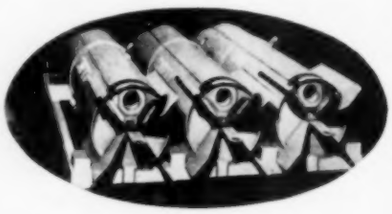
Shown below is a three compartment tank specially designed for washing castings in a large defense plant. Castings are successively passed through cold kerosene, hot cleaning solution



and finally hot water. The two hot baths are maintained at proper temperature by water heated in a steam converter and mechanically circulated through coils in the tanks. Operation and control of temperature is automatic. (No. 57)

Protective Refractory Coating

When applied to a new or clean surface, a liquid coating with the consistency of a light-bodied paint is said to definitely prolong and extend the normal life of brick or metal against the ravages of extreme heat. Coating is highly resistant to extreme heat (3500° F.) when applied and set by heat treating at approximately 1000° F., or by direct flame impingement. At the higher range of temperatures, a porcelain-like glaze is formed. (No. 58)

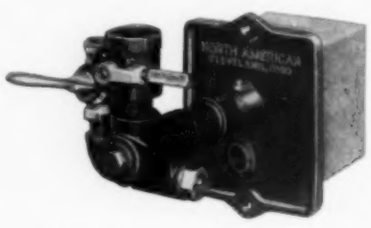


New Brazing Units

Problem of brazing a ¾-in. threaded flange into a completely closed 20-gage sheet steel container is solved by induction heating. Inductors are placed directly over the flange and heat it and a small area of the adjoining body. With this process it is possible to braze three units simultaneously in 35 sec. A ring of silver alloy, placed along the joint, melts and flows to form a perfect, air-tight seal. (No. 59)

Gas Burner

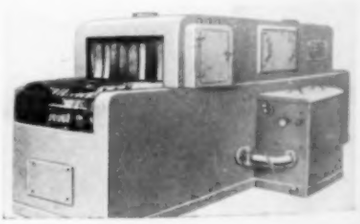
Pre-mixing aspirator type of gas burner with unique features incorporated in a complete factory-assembled unit, includes aspirator mixer, butterfly air control valve, full flow gas cock, and combustion tile — all assembled on a flanged mounting plate. Unit comes ready to be cemented in or bolted to the furnace wall. (No. 60)



Portable Wheelabrator

An entirely new development in the field of airless abrasive blast cleaning is illustrated. This portable unit marks a big step forward in metal cleaning because it is said to be adaptable to all

work that pressure blasting can do. It extends the advantages of airless centrifugal blasting to the blast room. (No. 61)

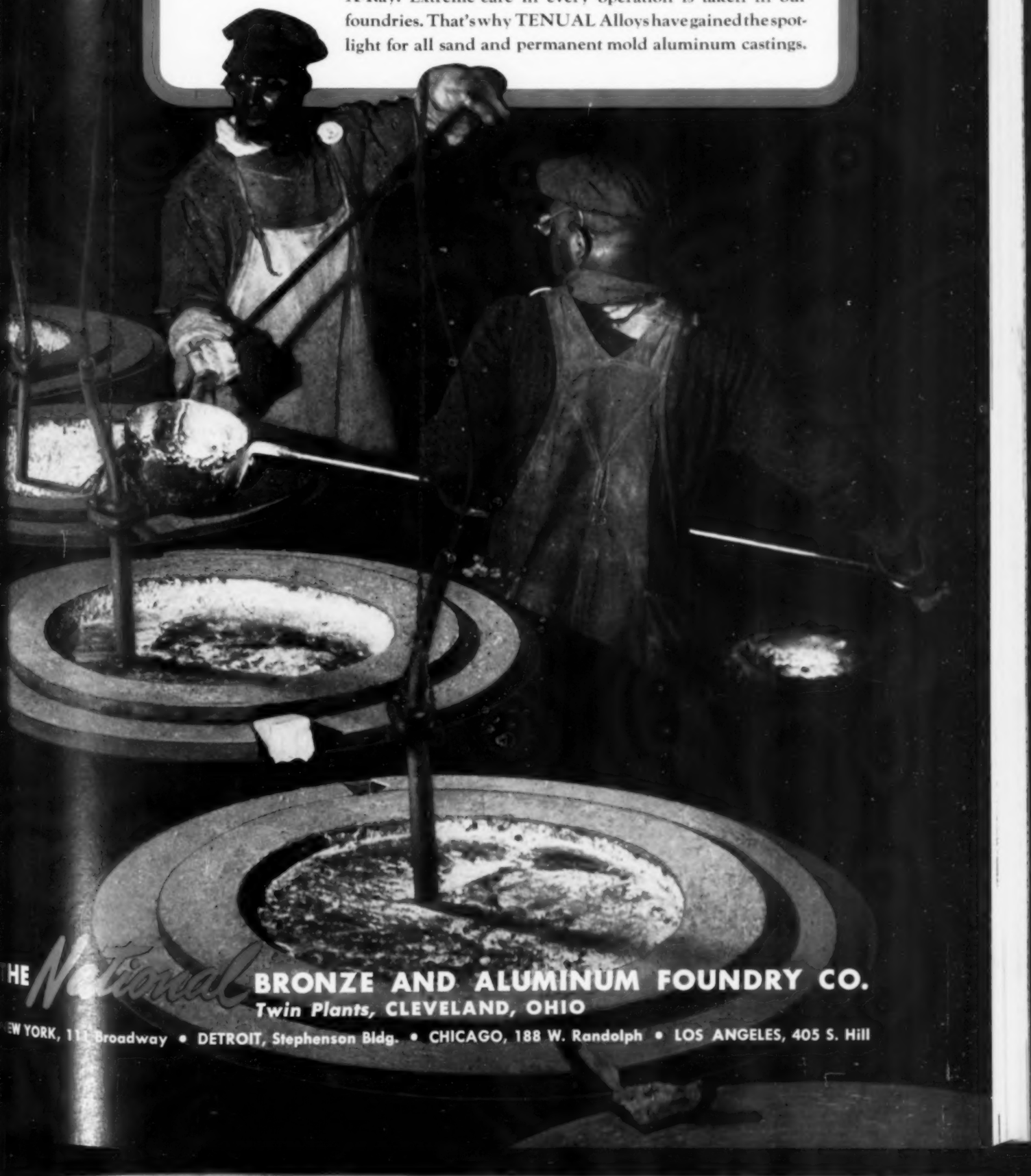


Metal Washing Machine

This new metal washing machine has been developed for use in connection with "emulso-dip" and "emulso-spray" processes, which represent special methods whereby metal parts can be cleaned more effectively and at lower cost than by many other methods now in use. (No. 62)

TENUAL

Melting is one of the most frequently overlooked practices in foundry business. To insure that our customers secure only the highest quality aluminum castings, so necessary for our armed forces, the melting and pouring of all TENUAL Aluminum Alloys is under automatic temperature controlled pyrometers along with the expert supervision of our experienced metallurgists. This close control prevents overheating which is so detrimental to physical properties. Chemical analyses and physical tests are taken from each heat of castings poured. In addition, we have complete X-Ray equipment to take care of all castings requiring X-Ray. Extreme care in every operation is taken in our foundries. That's why TENUAL Alloys have gained the spotlight for all sand and permanent mold aluminum castings.



THE National BRONZE AND ALUMINUM FOUNDRY CO.
Twin Plants, CLEVELAND, OHIO

EW YORK, 11[illegible] Broadway • DETROIT, Stephenson Bldg. • CHICAGO, 188 W. Randolph • LOS ANGELES, 405 S. Hill

As Others See Us*

FROM American journals of all types that reach us with regularity and abundance and from the occasional copies of German papers that still come to hand, it is possible to gain an idea of the state of the sciences in enemy and occupied countries, and the evidence available suggests that a certain amount of fundamental work is still in progress. In short, the condition of affairs is not very dissimilar from that obtaining in England. Professional and scientific workers in Great Britain must rely mainly on American journals for their information as to these foreign activities.

In addition to avoiding the language difficulty (on the whole) they have the advantage of a contrast in outlook which is stimulating and decidedly beneficial. Without belittling the value of the published matter, most readers will agree that the outstanding feature of all American journalism — and technical journalism is no exception — is in the advertising. The majority of these advertisements are superlatively well done. A few are inclined to set one's teeth on edge a little, particularly those of the pro and con debate type. Through all without exception runs the slogan "faster, bigger, and better", usually in that order, and a sense of headlong, ever-accelerating competition. In one case we remember noting a depressing reference in an advertisement for electric welding generators to the post-war struggle for business, which is apparently anticipated as inevitable.

Of the printed matter, one may distinguish several divisions. Editorials, and not infrequently general articles, often contain political references, sometimes savagely criticising the economics of Mr. Roosevelt's administration, but never pro-Nazi in tone. The freedom and hard hitting quality of American opinion is certainly refreshing to more conservative British minds. Technical articles themselves are in general excellent, and in the particular field of welding have already contributed much to straighten out the tangle of this complex subject. Particularly noticeable is the frankness with which research data are contributed and the exhaustive manner in which all literature is combed for references. In this respect, the American welding industry compares with any in the world, and one very pleasant feature is its freedom from the fault of ignoring, or failing to quote work carried out by foreign workers.

*Editorial, "Foreign Technical Journals", in the December issue of *The Welder*, the house publication of Murex Welding Processes, Ltd.

From Coast . . . To Coast

The Talk of the Machine Shops Wherever Boker's Tool Steels are used - - - - - - - "They Satisfy!"

NOVO — 18-4-1 Type High Speed Steel.

TWIN MO — 6-6-2 Tungsten Molybdenum High Speed Steel.

KINITE — High carbon, chrome, air hardening bar steel and castings.

For over 105 years we have served the industry and we are proud of it.

EST. BOKER 1837

H. BOKER & CO., Inc.

101 DUANE ST. • NEW YORK

Critical Points

(Cont. from page 813) — all are needed, and of these "the crux of the problem of the shipbuilding industry today is the development of smoothly functioning organizations". (So says HORACE GILBERT in a careful study of the problem in *Harvard Business Review*.)

HEARD something of the steel warehousemen's plight from WALTER DOXSEY, president of their association — a fix doubtless shared by other men handling small orders for any large metal industry, or even by producers of widely used metal objects like welding rods. Required by law to sell to anyone with a rating above A-10, they cannot replenish their stocks unless the delivery has been to an A-1 priority, and even then they get no more than a quota based on business in 1941, before the real rush began. Result — a steady depletion of stocks, and a mounting inability to ship small quantities promptly for emergencies or to small sub-contractors who need a few hundred pounds of steel rather than a few hundred tons.

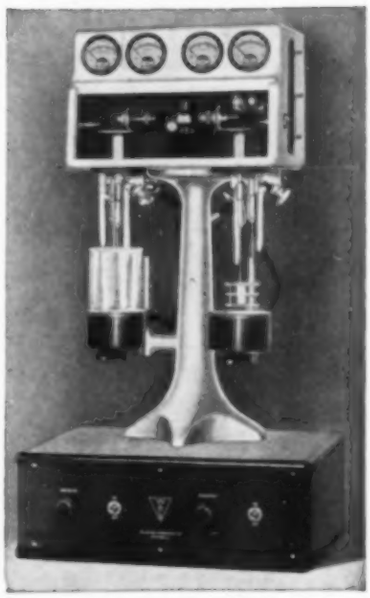
Vanishing Warehouse Stocks

The Army Ordnance Department has recognized this dangerous situation, but instead of seeing to it that established warehouses get the necessary steel, "the Government" sets up a central stock, financed by Metals Reserve Co., to serve the scattered manufacturers of parts for small arms! . . . . . For some months there has been vigorous argument as to whether it would be better to lay aside stocks of metal, plates and shapes, earmarked against an emergency such as a battleship repair, or to keep warehouse stocks at a level for complete turnover every three months (as at present). So far the proponents of earmarked stocks seem to have the decision. . . . . CONSTRUCTIVE FOOTNOTE: When there's any choice, extend your *highest* priority ratings to your warehouse, for gosh, they certainly can use it!

GEM of the Month, by JOSEPH GOLLOMB in *The New Yorker* for May 23, in writing about a tabulating machine: "The operations of this glittering mechanism are too complicated for the tensile strength of non-technical$_A$ expository prose." Ruefully THE EDITOR inserts, "or technical".

★ ★ ★ ★

WACO
TWIN UNIT
ELECTROLYTIC
APPARATUS



★ **Independent Operation**

of each unit, in respect to electrolysis current control, polarity reversal and speed of electrode has always been featured in WACO Electrolytic Apparatus. Both voltage and amperage are CONTINUOUSLY indicated for EACH unit. The new design includes control of all physical factors, proven in preceding models, and greater convenience, with ease and speed of operation.

★ **Automatic Electrode Washing**

prevents dissolving of the deposited material. The electrode is safely removed and COMPLETE recovery of the deposit is certain.

★ **Instantaneous Release**

of electrode is accomplished by simple pressure of index finger and thumb . . . with the WACO chuck. Eliminates the inconvenient threaded end of old style holders.

The WACO Swinging Arms avoid supports of cumbersome wood blocks . . . as a touch of the finger is sufficient to swing the WACO arms aside for easy removal of electrodes!

Constant electrode speed must be assured in order to obtain check results. The WACO, therefore, employs a CAPACITANCE INDUCTION motor, which operates independently of usual line fluctuations.

★ **Most Laboratories**

AT TIMES, desire to make Micro determinations. Accordingly, the WACO is supplied with double scale meters, 0 to 150 M.A. and 0 to 3 Amp., making it a UNIVERSAL instrument. *Three shafts are incorporated so separate glass stirrer may be used.*

★ **Among the Users**

Aluminum Co. of America (6)
American Optical Co.
Columbia Tool Steel Co.
Commercial Solvents Corp.
Continental Can Co.
American Rolling Mill Co.
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E. I. du Pont de Nemours (4)
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General Electric Co.
General Foods Corp. (4)
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Lewin Metal Corp.
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Sears, Roebuck & Co.
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Weirton Steel Co.

★ **WACO Electrolytic Apparatus**

No. 3520 ML. TWIN UNIT. Individual control of electrolysis current and speed with DOUBLE scale meters. Induction Motor for 110 V.A.C. With Directions and Procedure..... **$162.00**
No. 3520W. Automatic Washing System, extra.... **$13.50**

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Write for bulletin MP642 describing the WACO Electrolytic Apparatus, mentioning best priority rating available! Wilkens-Anderson Co., 111 N. Canal Street, Chicago, Illinois.

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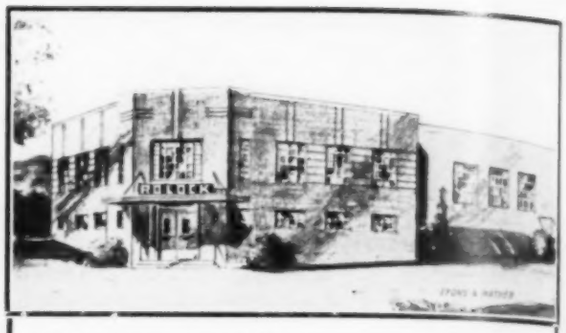

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INDUSTRIAL BASKETS AND CRATES

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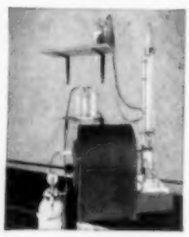
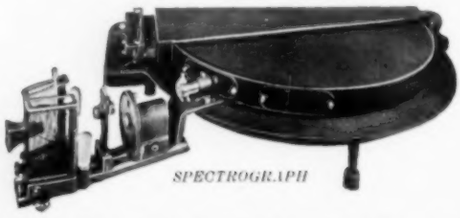
MODERN ANALYSIS



Carbon Determinator

Carbon and sulphur determinations may be made within six minutes after the molten metal is taken from the furnace. Accuracy is not sacrificed for speed. The molten metal is poured into the Specimen Mold. The resulting test specimens are weighed and placed in combustion boats for carbon and sulphur determinations. The carbon is determined accurately by combustion-volumetric methods and the sulphur by the combustion-titration method.



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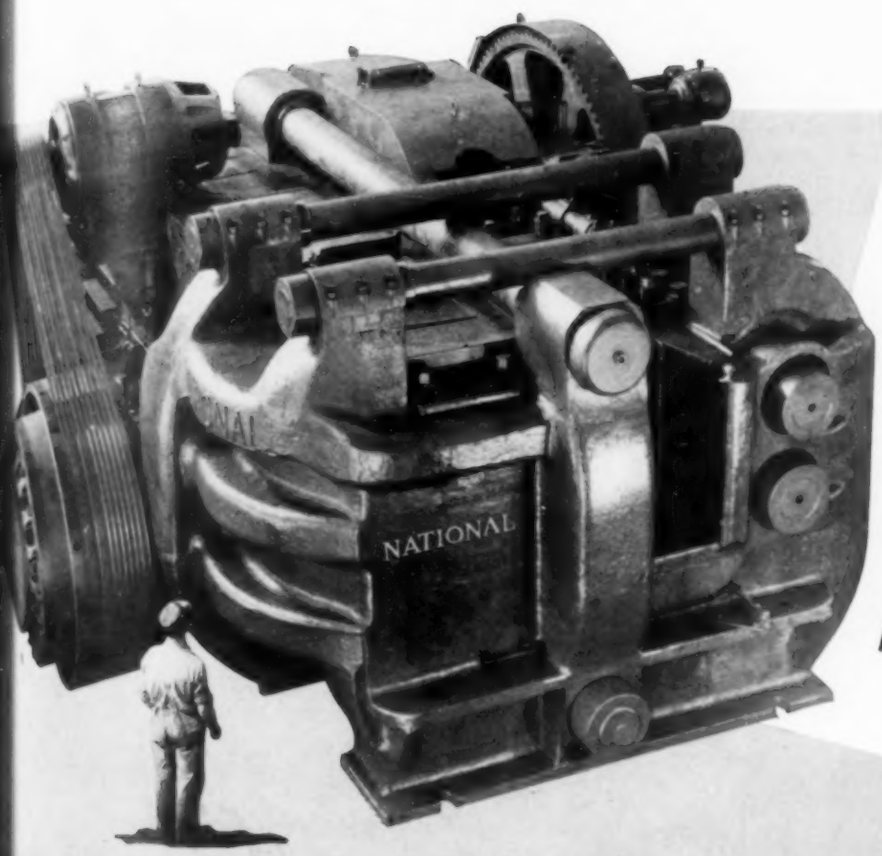
STEEL CASTINGS



make BETTER forgings possible

Sounds a little inconsistent, doesn't it? For in some applications, forgings and castings are pretty active competitors.

Still the frame of this giant forging machine, designed for producing airplane cylinders, is made of steel castings —for rigidity, for precise accuracy and for economy. The machine is the largest of its kind ever built and weighs over 500,000 pounds.

This is typical of the thousands of jobs steel castings are doing to advance our war production effort—to deliver vastly increased numbers of guns and tanks and ships and planes.

When it comes to building things better and quicker and at less cost, engineers and designers are inclined to look into steel castings FIRST. They require less time to prepare for production. They make available all the desirable properties of steel—strength, hardness, rigidity, resistance to fatigue and stresses and resistance to extremes of heat, cold and pressure.

They often introduce new economies by combining many parts in a single casting—saving finishing and assembly time. They reduce the handling and machining off of needless metal, and make it easy to get weight and strength exactly where they are needed most.

May we suggest that you discuss both old and new production problems with your steel foundryman. Or you may communicate—no obligation of course—with Steel Founders' Society, 920 Midland Building, Cleveland.

MODERNIZE AND IMPROVE YOUR PRODUCT WITH

STEEL CASTINGS

Copper Scrap

(Cont. from p. 821) following table can be computed:

Year	Recovery as Metal and in Alloys	Tons of Refinery Secondary	Recovered by Other Portions of the Industry
1935	448,900	148,500	300,400 net tons
1936	484,600	132,900	351,700
1937	532,100	156,600	375,500
1938	359,800	92,500	267,300
1939	499,700	116,600	383,100
1940	532,000	117,600	414,400
Totals	2,857,100	764,700	2,092,400 net tons

It would be desirable to know what proportion of the metal indicated in the last column was handled by each of the two general types of plants: *(a)* Remelters, and *(b)* manufacturers and foundries.

Remelters comprise numerous firms, a dozen or more of importance as well as three or four dozen small concerns, which are prepared to accept some 30-odd classifications of copper, brass and bronze scrap (either as manufacturers' new plant scrap, or old scrap demolition metal from wholesale junk dealers) and remelt it into ingots of known composition. Their product is the principal source of ingot metal of the non-ferrous foundries; only one of the principal remelters normally produces rolling mill billets of unalloyed metal (wire bars) or composition (free-cutting rod analyses).

The remelting firms have a trade association, The Non-Ferrous Ingot Metal Institute at 308 W. Washington St., Chicago. R. D. T. Hallowell is secretary. This institute has collected and published monthly tonnage shipments, expressed as weights of ingot shipped. Not all remelters are members of the Institute, but during the period under review its membership was fairly steady and accounted for about two-thirds of the total output. It is also estimated that the average copper content of brass and bronze ingot produced contains about 80% copper, so on both bases the Institute's figures may be increased by 20% in order to represent *copper* content of the entire amount of remelted ingot. Combining these figures with those given in the last table we have Table II, page 821.

A general check on the accuracy of this distribution is had from the more detailed statistics gathered by the Bureau of Mines in 1939. In that year refiners and remelters accounted for 237,700 tons or 48% of the secondary copper; manufacturers and foundries 262,000 tons or 52%. The figure 297,600 for manufacturers and foundries derived in Table II for 1939 is apparently high; however, for

(Continued on page 884)

with the R. R. MOORE FATIGUE TESTING MACHINE

Operating at speeds of 10,000 rpm, the R. R. Moore high speed Fatigue Testing Machine is equipped with a variable speed drive—an essential feature in the testing of certain alloys which heat up when highly stressed. It also allows correlation of high speed tests with previous lower speed tests.

The machine is based on the rotating beam principle, and the specimen functions as a simple beam symmetrically loaded at two points. Hence the specimen is under *constant bending moment*, and during one complete revolution the test specimen passes through a complete cycle of flexural stress.

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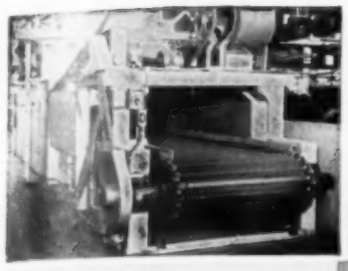

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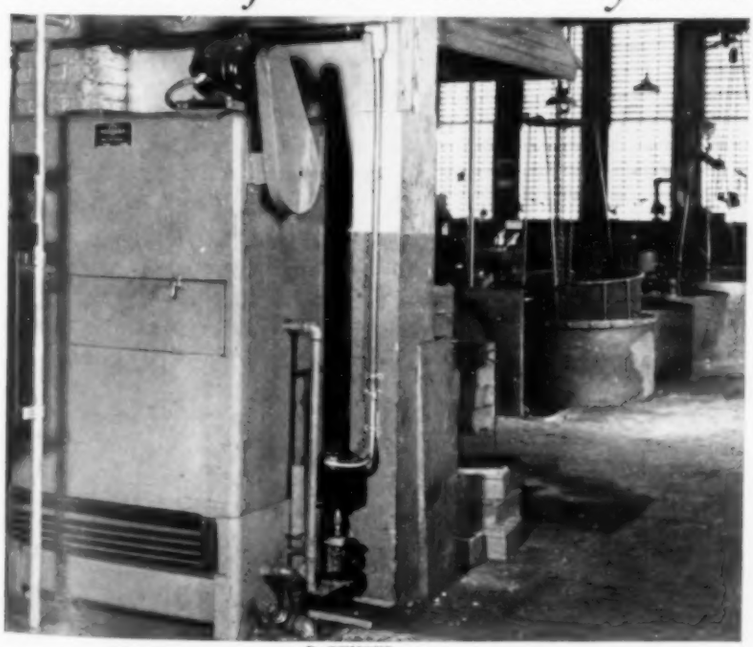

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Copper Scrap

(Starts on page 819)

the entire six years the refiners and remelters (as derivable in the table) recovered 45% of the secondary copper and the manufacturers and foundries 55% — a figure closely checking the Bureau of Mines figures for 1939.

It should be noted that in the "manufacturers and foundries" group listed in the 1939 and 1940 Bureau of Mines Statistics, "manufacturers" are principally the brass rolling mills; they have melting shops, and consequently can rework their own plant scrap. (Copper and wire mills rolling pure copper ordinarily have no melting furnaces.) The non-ferrous foundry industry, comprising 2500 plants, more or less, also remelts sprues, risers, defectives — new scrap occurring during their normal operations. In addition to new plant scrap, the manufacturers (brass mills) but particularly the non-ferrous foundries purchase large quantities of old scrap (junk from demolition operations, or discarded articles of consumers' goods). Obviously a remelted sprue originating in the same foundry is not "secondary copper"; it is circulating metal in process, and it is sometimes difficult to determine whether that same sprue, if sold to another firm for remelting, is "metal in process" or "new scrap".

In 1939 the Bureau of Mines reported that 65% of the secondary copper recovered by manufacturers and foundries was obtained from new scrap, and 35% from old scrap. (The figure of 57% of old scrap for 1939 in Table II includes copper recovered by refineries.) In view of the expanding nature of the brass industry, the relative amount of new scrap is bound to increase. The old scrap bought by mills and foundries, in any case, is easily usable scrap; in other words, a brass mill unless under some sort of compulsion would not buy off-analysis brass scrap; obviously, a foundry making yellow brass radiator valves would normally buy old radiator valves and remelt them. The principal reaction that such purchases of choice grades of scrap have on our general problem of best use of reclaimed metal in such dislocated times as these is, therefore, that mills and foundries, particularly the latter, entered the old scrap market in the closing months of 1941 and absorbed unusual tonnages of metal of desirable composition, thus degrading the quality of the remainder available to remelters of alloy ingots.

In concluding this preliminary inquiry into the *size* of our problem, that is, the tonnage of metal that is involved, it should

(Continued on page 888)

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Copper Scrap

(Starts on page 819)

be evident that our total resources in secondary copper available for new objects of manufacture, able to supplement new copper produced from mines, is limited *in a period of steady industrial activity* to a figure equal to the recovery from old scrap (junk, or articles from demolition). *In periods of decreasing industrial activity*, on the other hand, some of the metal in process is used up for the production of consumer goods. *In an expanding period*, such as the present when the circulating load of "new plant scrap" is increasing, the addition to our copper available for use is considerably less than the total recovered from junk.

The situation will be greatly intensified by the fact that articles are ordinarily discarded only when new articles are available for replacement, and as far as consumer goods are concerned, replacements are now very sharply restricted. The building industry, for instance, cannot be expected to yield anywhere near its normal amount of brass and copper from wrecked residences and buildings.

From these considerations, therefore, it may be concluded that in the period 1935 to 1940 inclusive, the gain in useful copper is much closer to the 2,000,000 tons, more or less, secured from old scrap (demolition) than to the approximately 3,000,000 tons of total secondary copper reported in the statistics. The higher figure comes from the inclusion each year of about 150,000 tons of new plant scrap, which is merely a recirculating load of metal in process. It is an obvious conclusion, also, that in this time of emergency, the only secondary copper that really augments our supply is the junk that can be recovered. (Of course, manufacturing improvements that reduce the amount of circulating plant scrap — as by lower machining limits — are also most desirable.)

From the above it appears that the data being accumulated by W.P.B. about tonnage of secondary metal (other than own plant scrap) now coming into manufacturers, brass mills, and foundries, should be studied in order to determine whether concentrations of metal are being accumulated which are not readily or promptly usable. Diversion of such metal should be made to other plants better equipped to handle it promptly. Likewise, worthy of serious attention are ways and means of restarting an even larger collection of discarded and obsolescent copper, brass and bronze articles, to replenish the dwindling supply to be anticipated.

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